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Xiao et al.

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(54) **COVERED STENT**

(71) Applicant: **Lifetech Scientific (Shenzhen) Co., Ltd.**, Shenzhen (CN)

(72) Inventors: **Benhao Xiao**, Shenzhen (CN); **Caiping Liu**, Shenzhen (CN); **Da Li**, Shenzhen (CN)

(73) Assignee: **Lifetech Scientific (Shenzhen) Co. Ltd.**, Shenzhen (CN)

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CPC ***A61F 2/07*** (2013.01); *A61F 2002/077* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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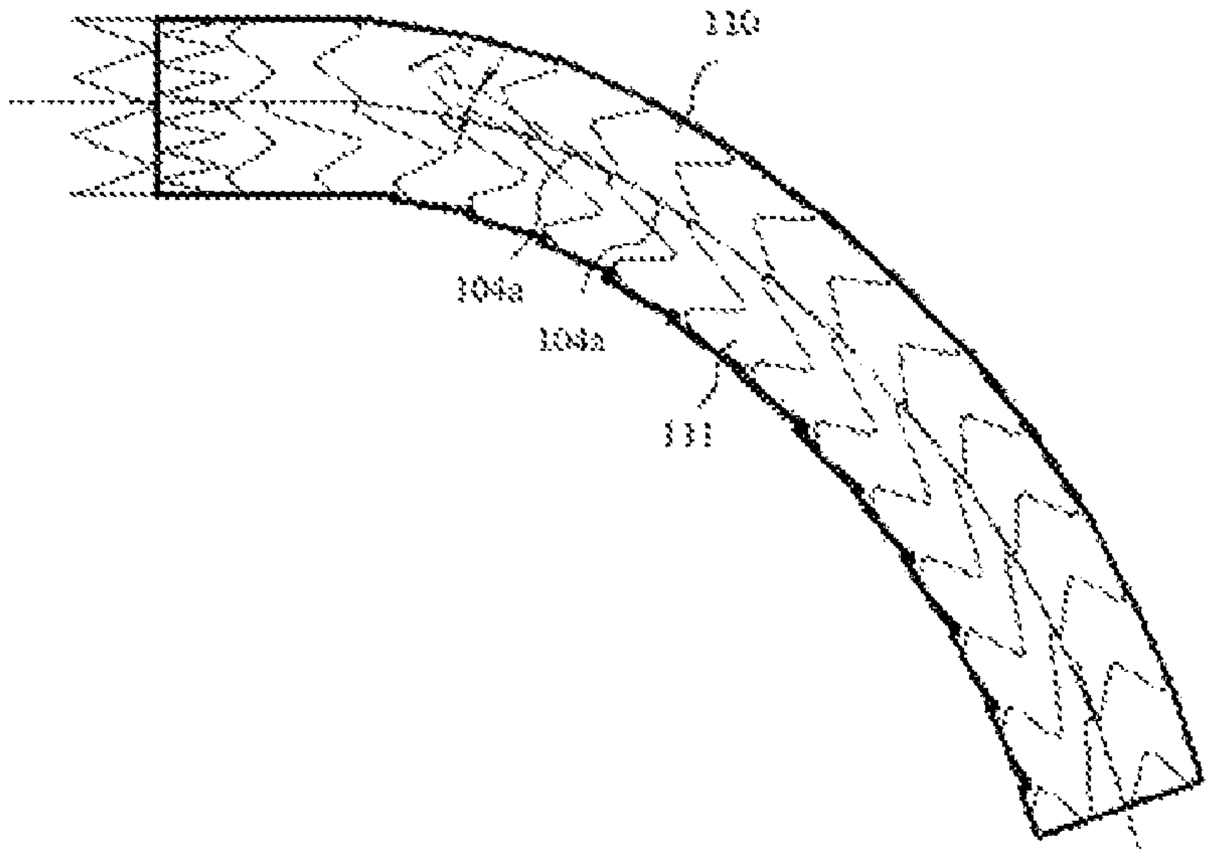
Primary Examiner — Ann Schillinger
(74) *Attorney, Agent, or Firm* — Raymond Sun

(57) **ABSTRACT**

A stent graft comprises a plurality of wavy rings sequentially arranged in a spaced manner, and membranes fixed to the plurality of wavy rings, wherein the stent graft comprises, in a circumferential direction, at least one keel region and a non-keel region connected to the keel region, the keel region having an axial shortening rate that is less than that of the non-keel region, and the axial shortening rate of the keel region is 10-40%. The stent graft can be bent in all directions, and the keel region on the stent graft can provide a sufficient amount of an axial support force for the stent.

10 Claims, 7 Drawing Sheets



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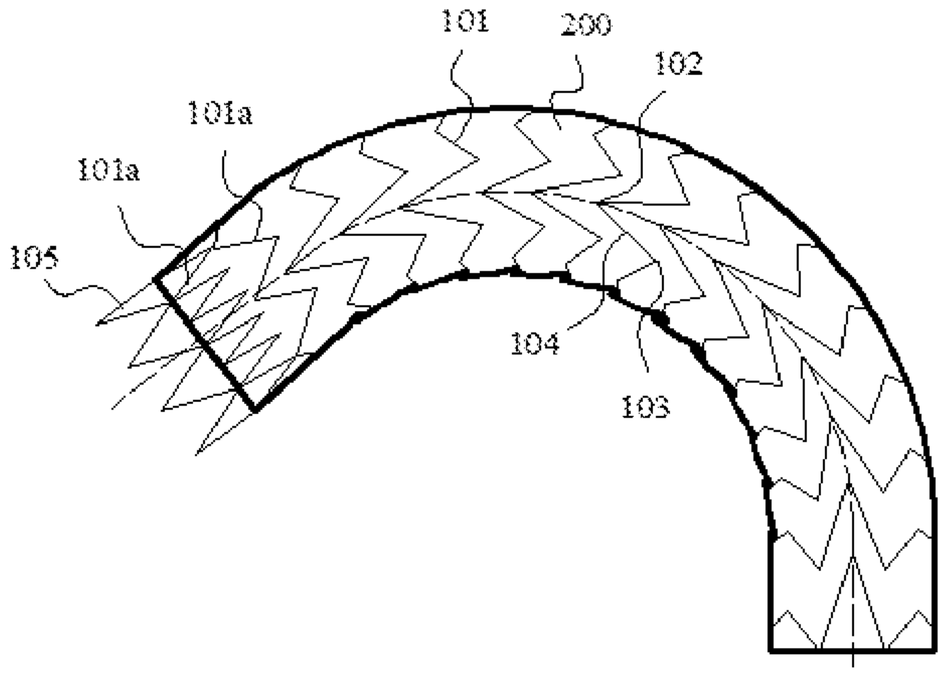

Fig.1

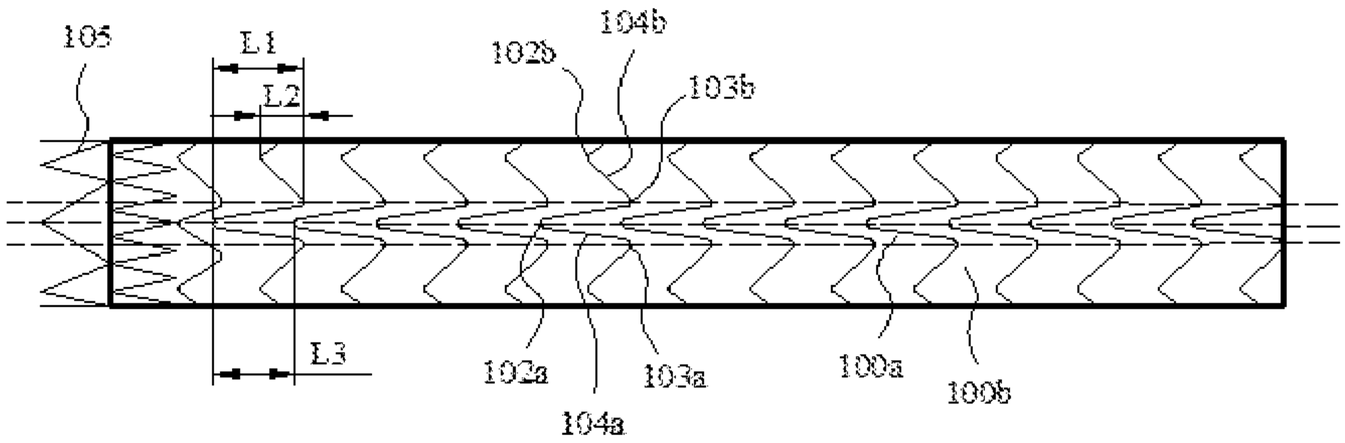

Fig.2

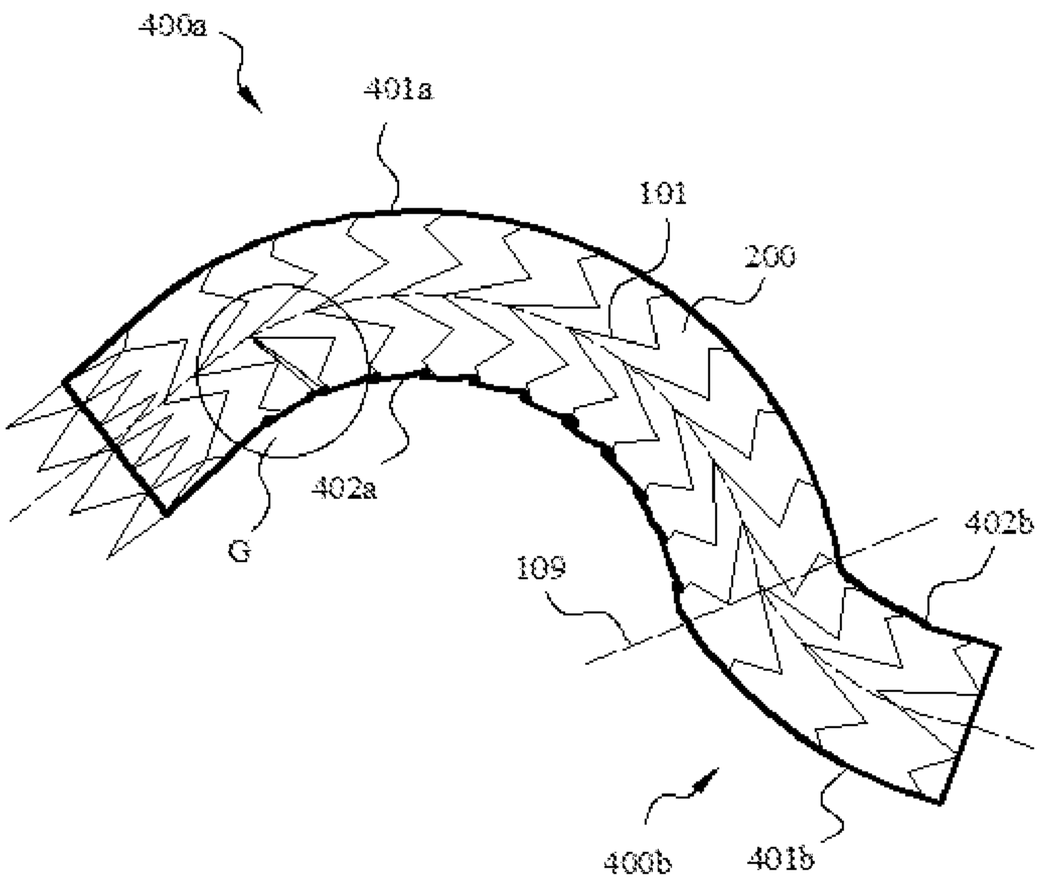

Fig.3

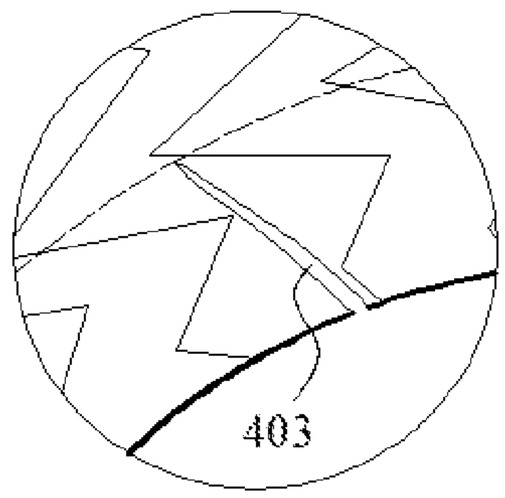

Fig.4

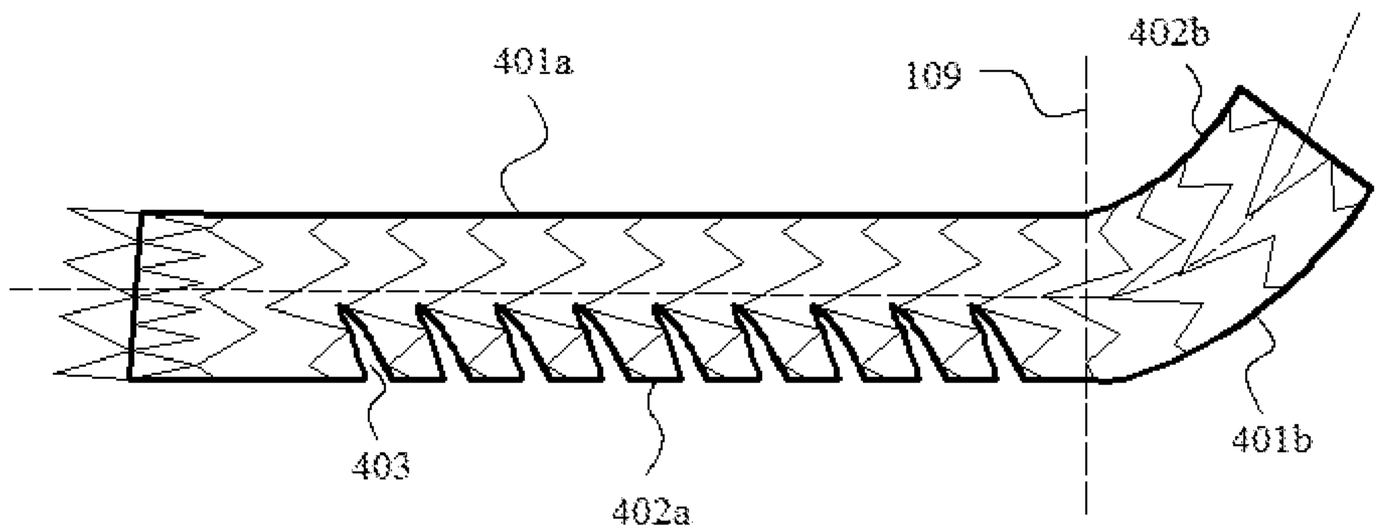

Fig.5

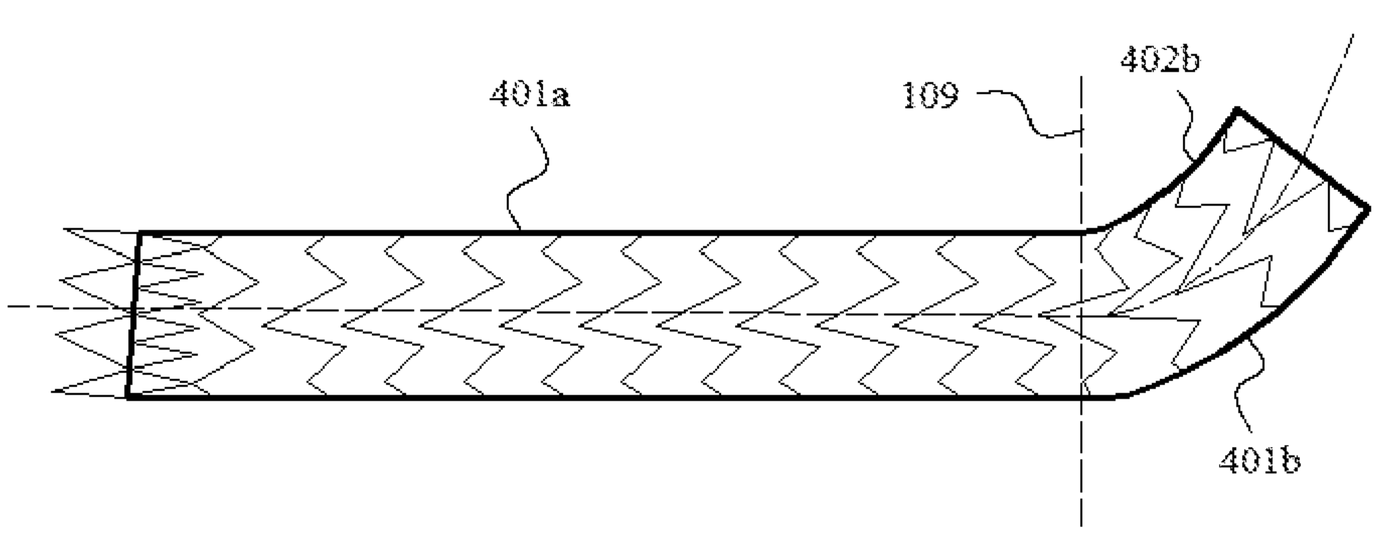

Fig.6

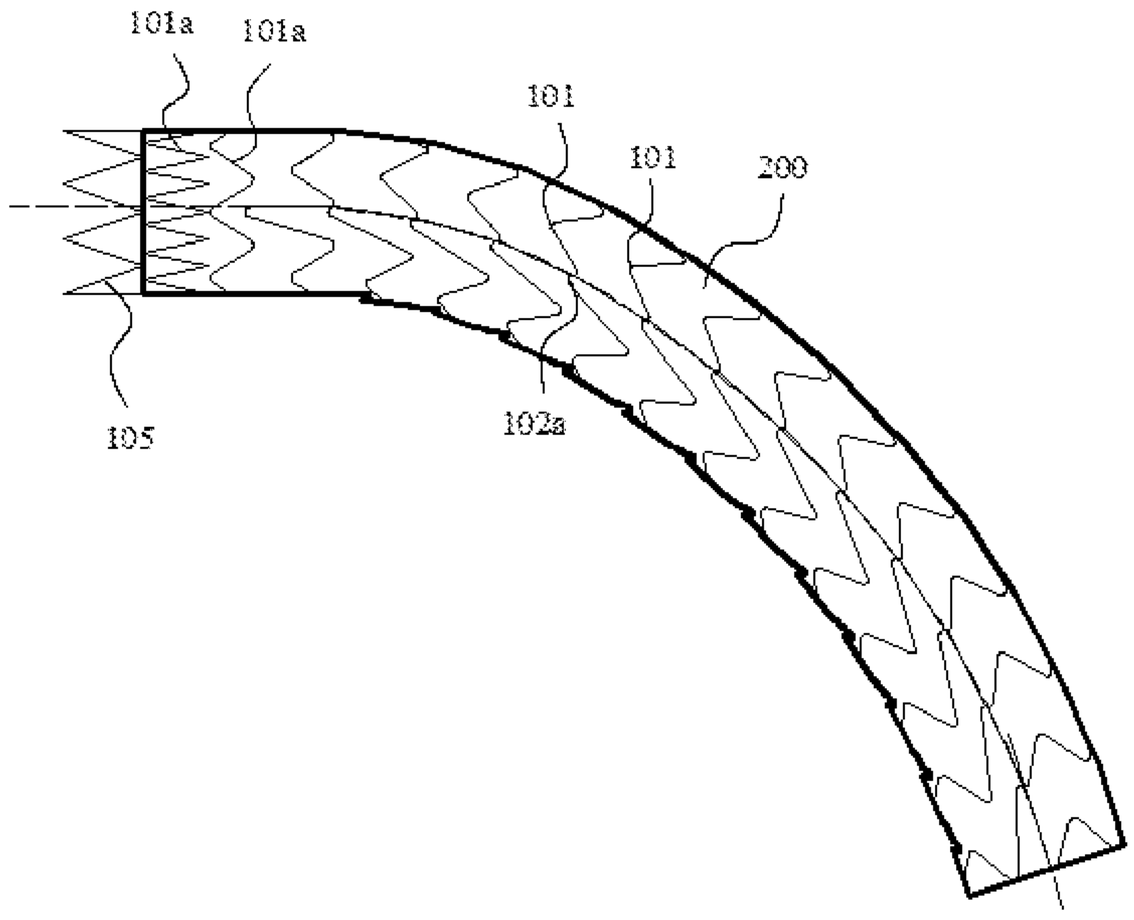

Fig.7

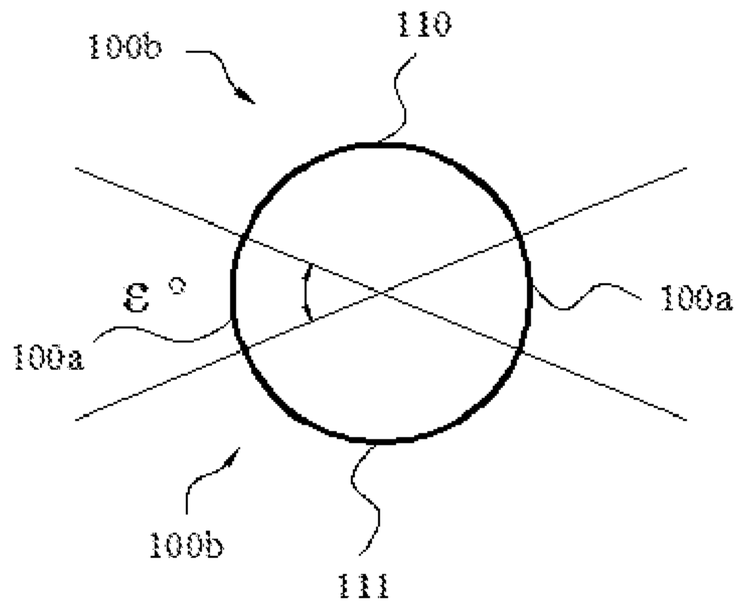

Fig.8

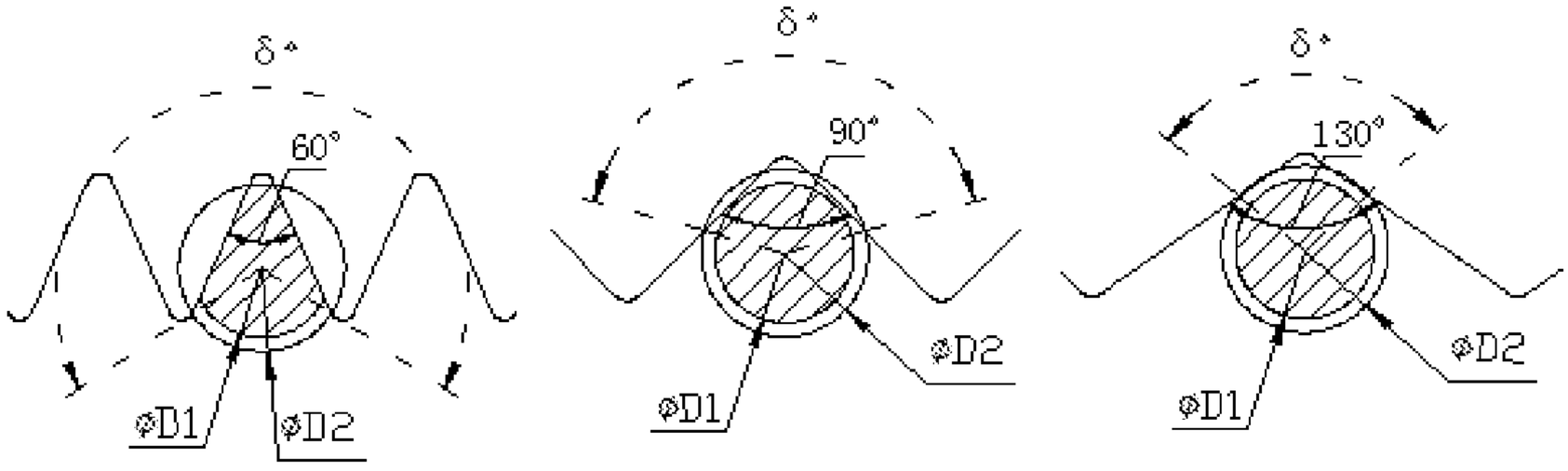

Fig.9a Fig.9b Fig.9c

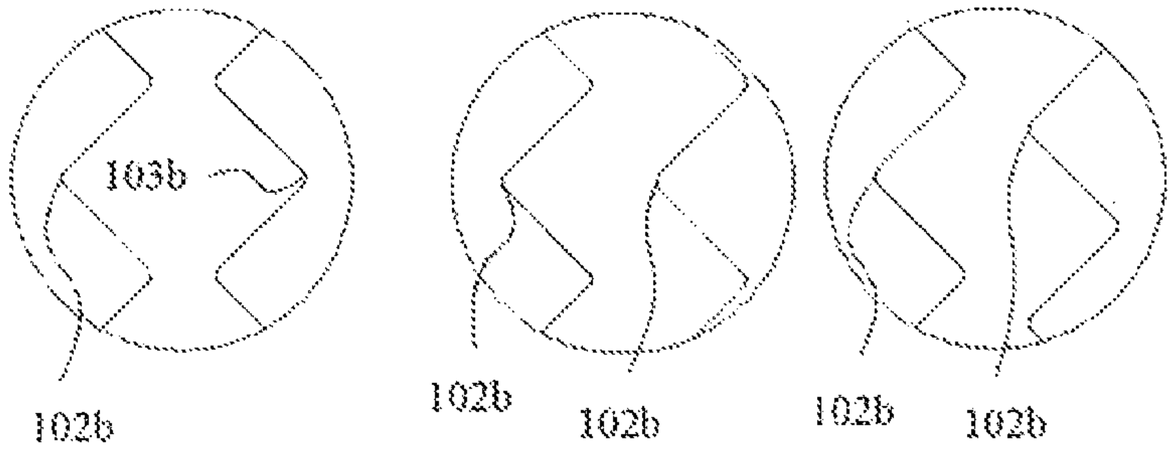

Fig.10a Fig.10b Fig.10c

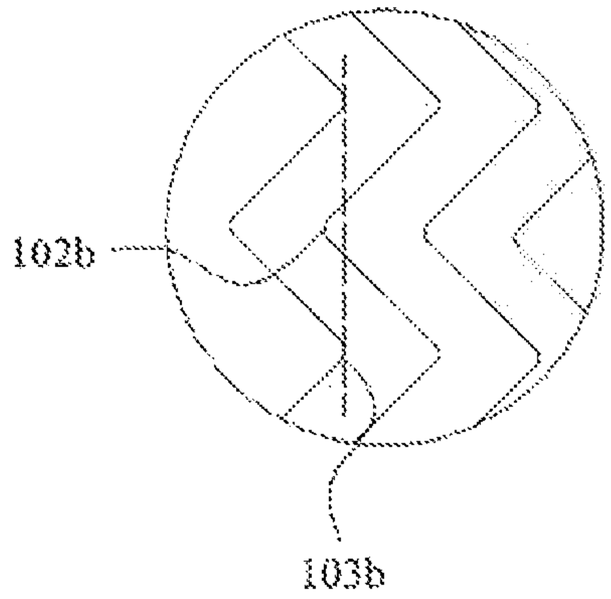

Fig.11

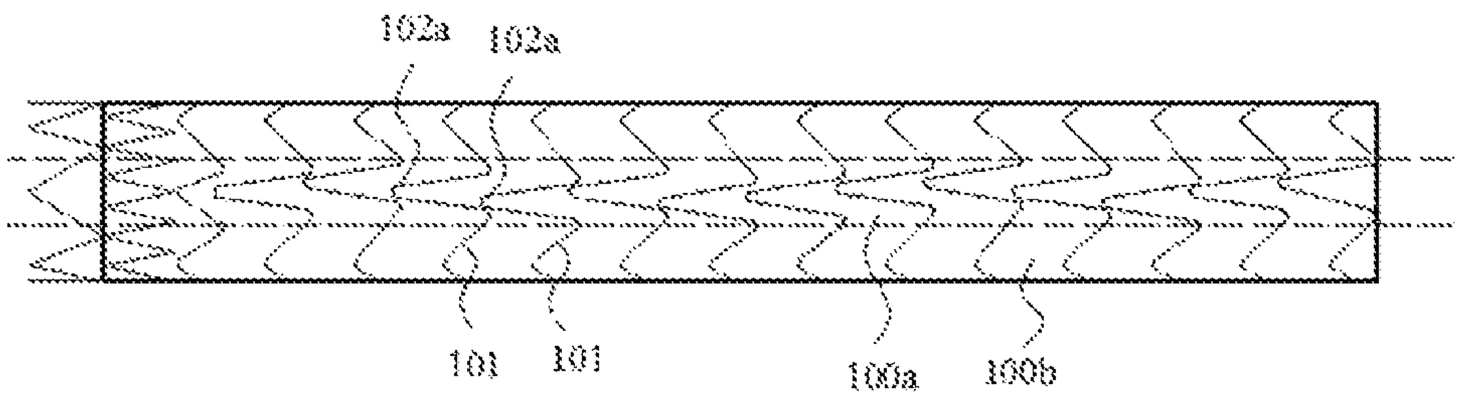

Fig.12

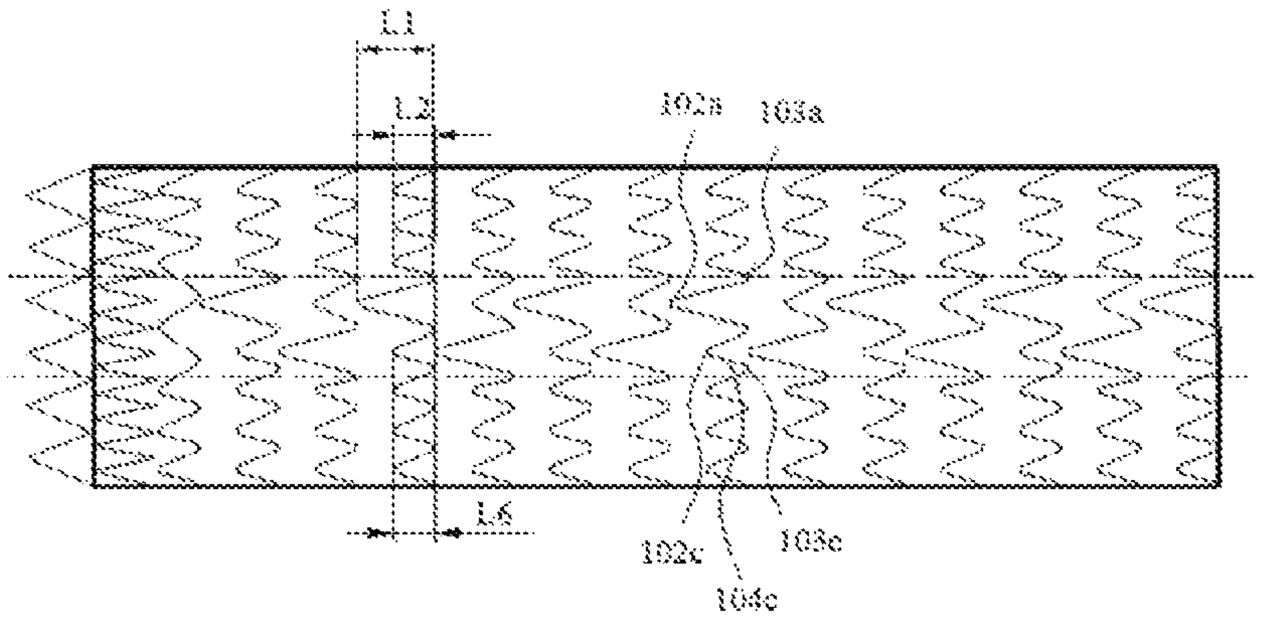

Fig.13

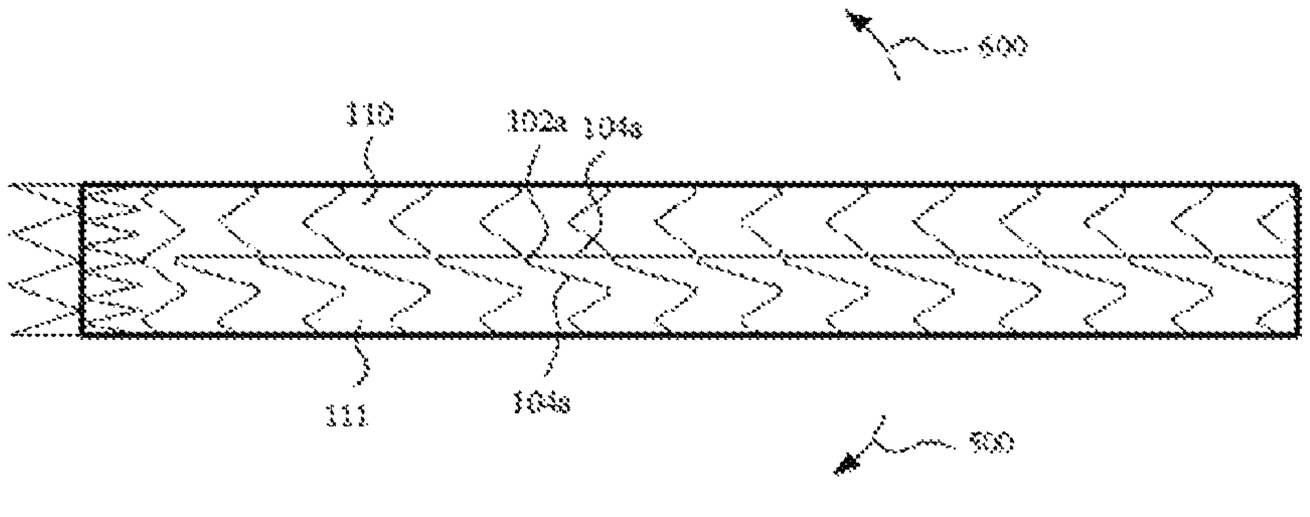

Fig.14

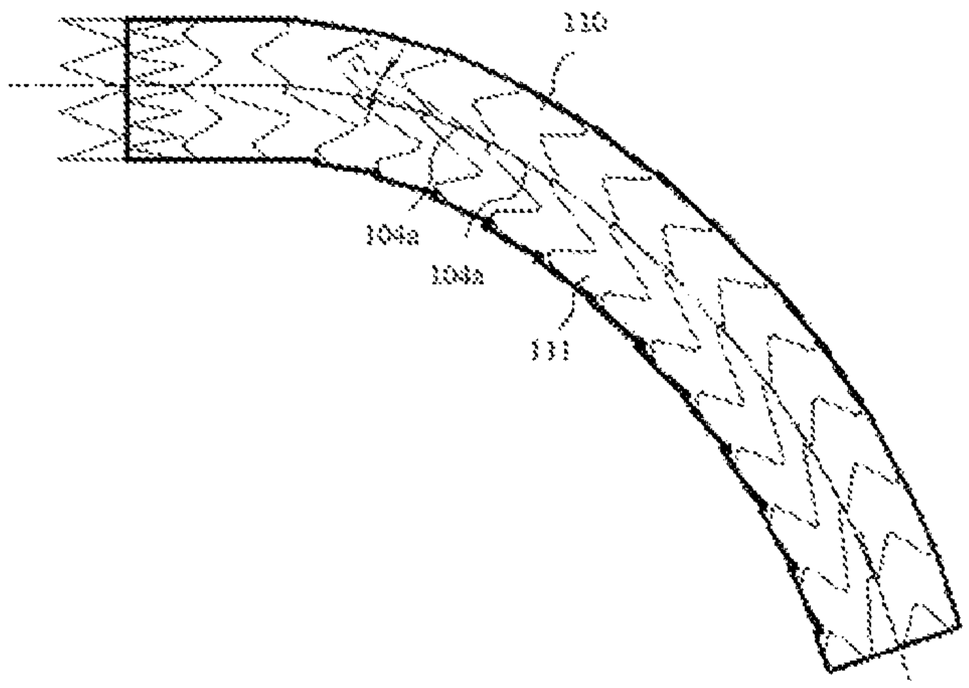

Fig.15

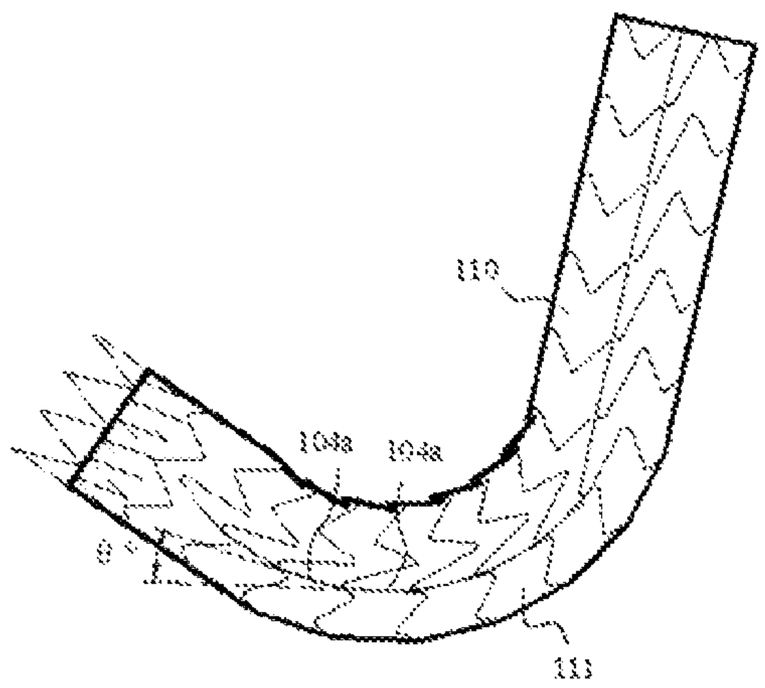

Fig.16

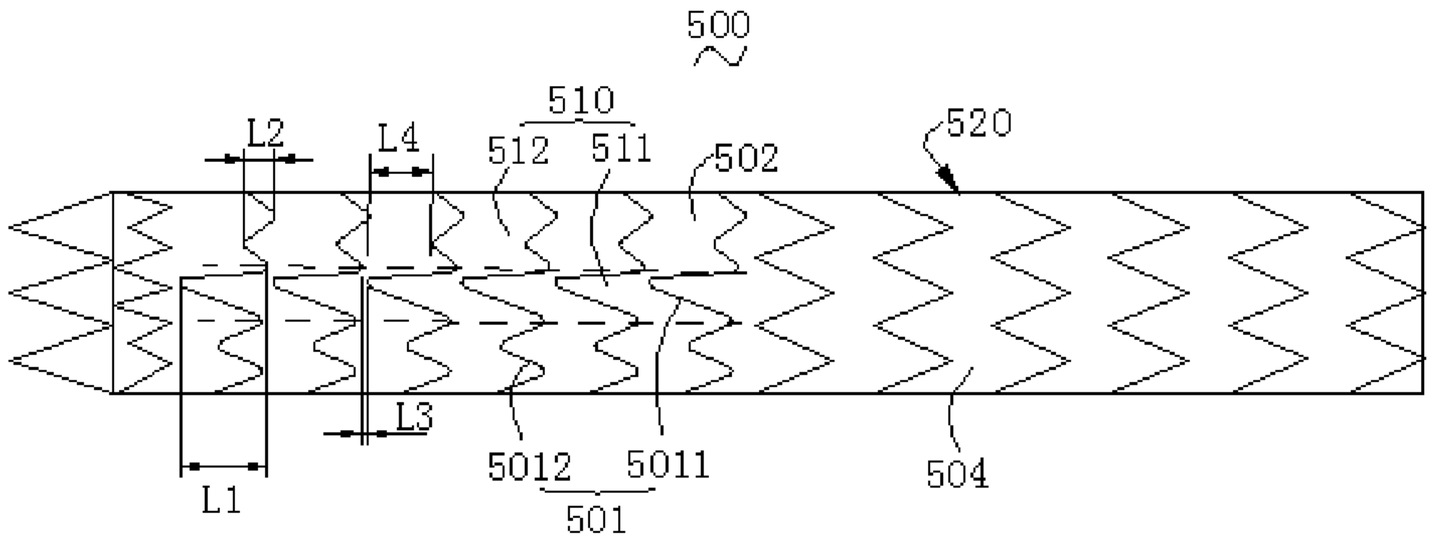

Fig.17

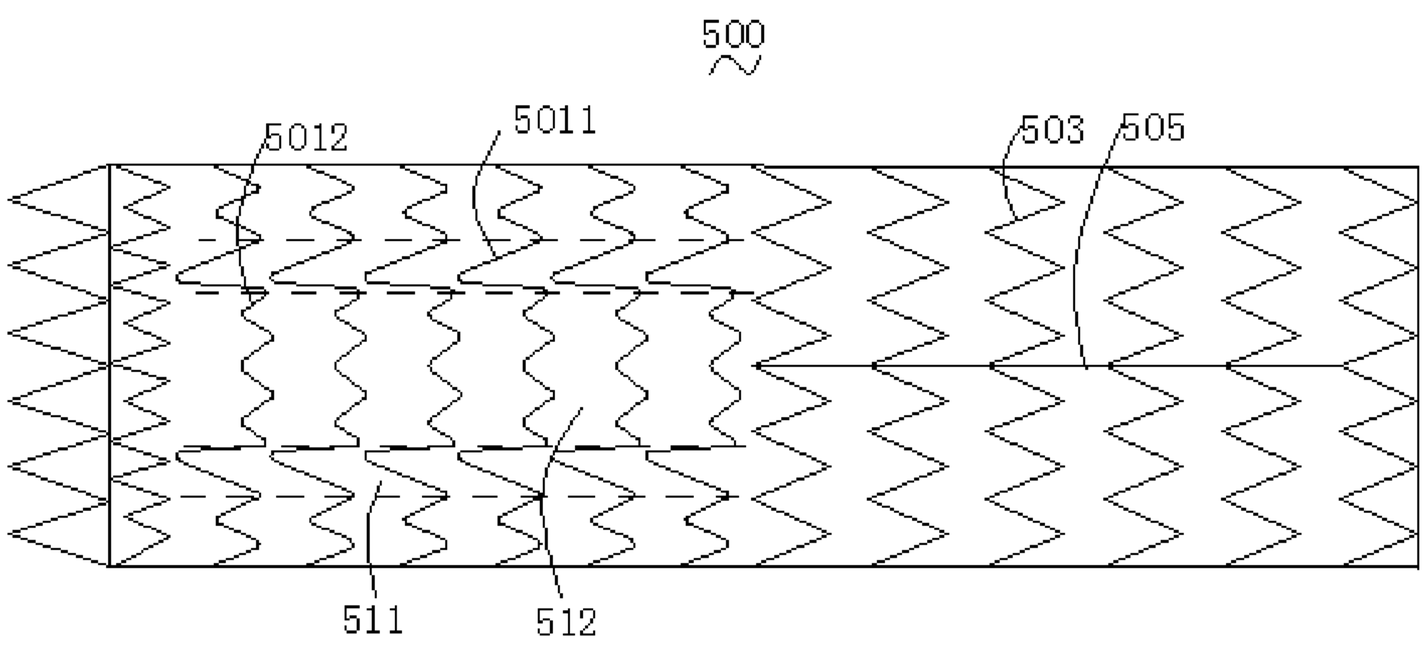

Fig.18

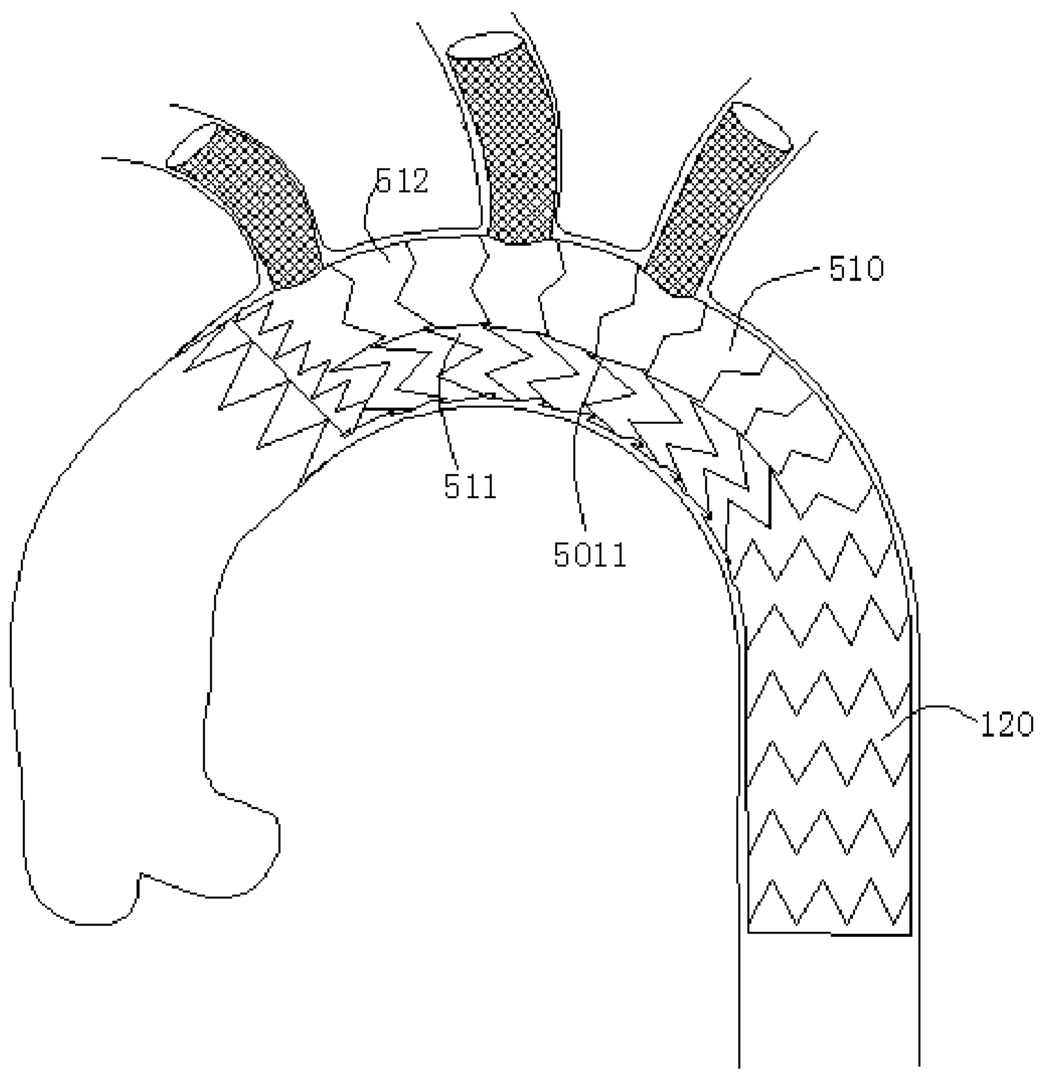

Fig.19

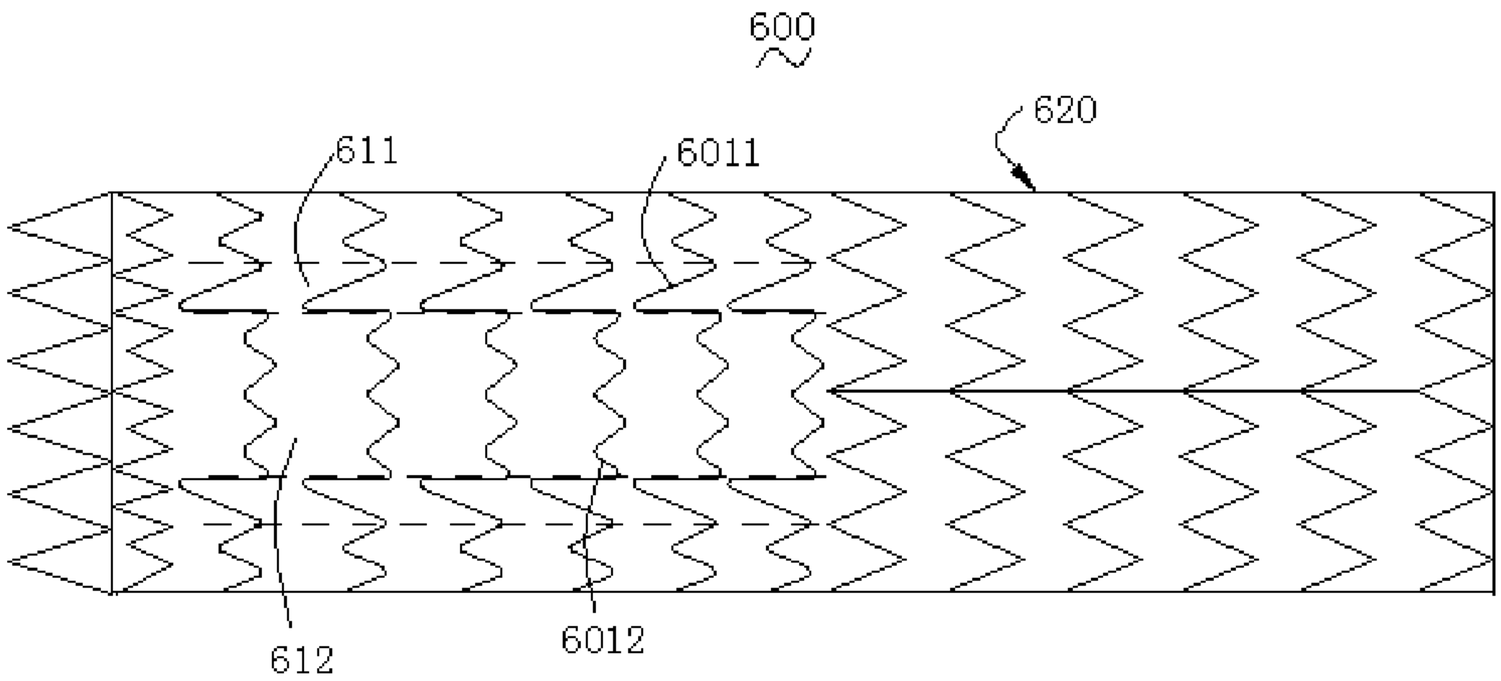

Fig.20

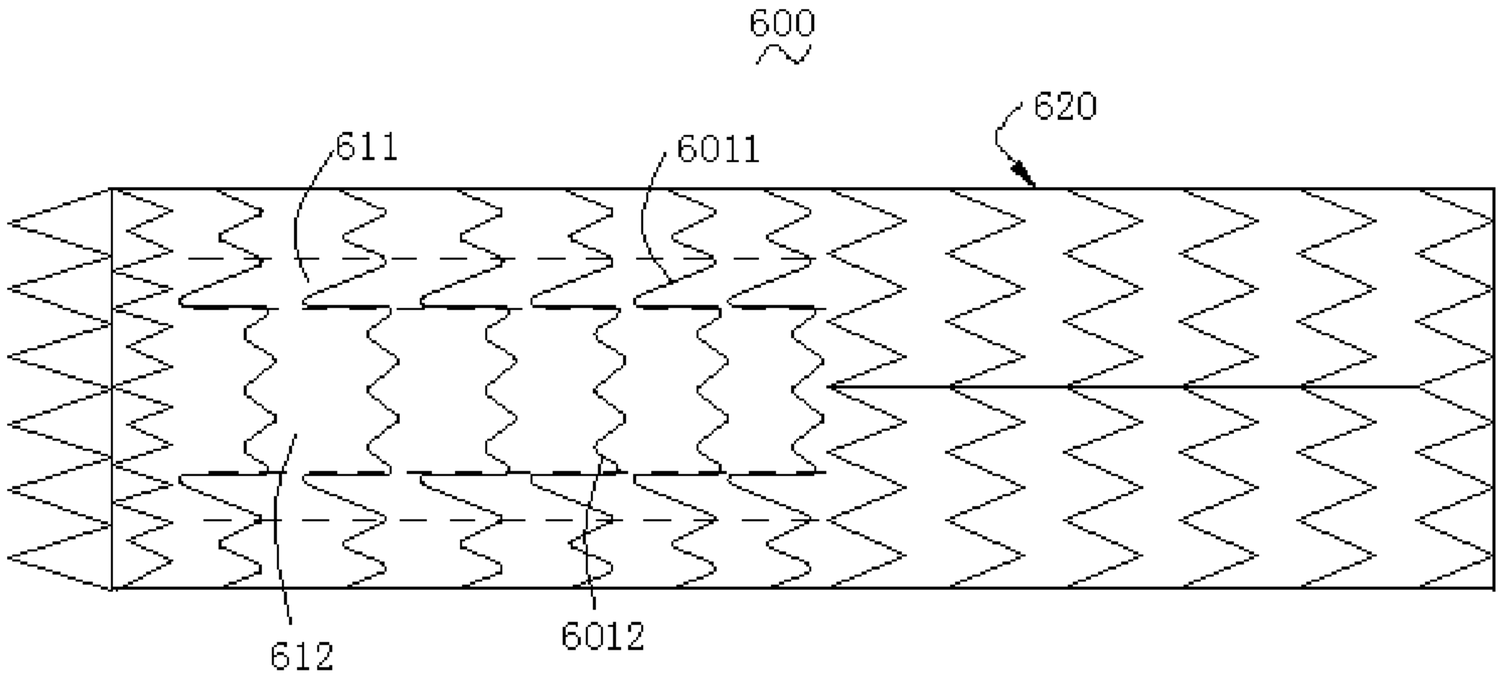

Fig.21

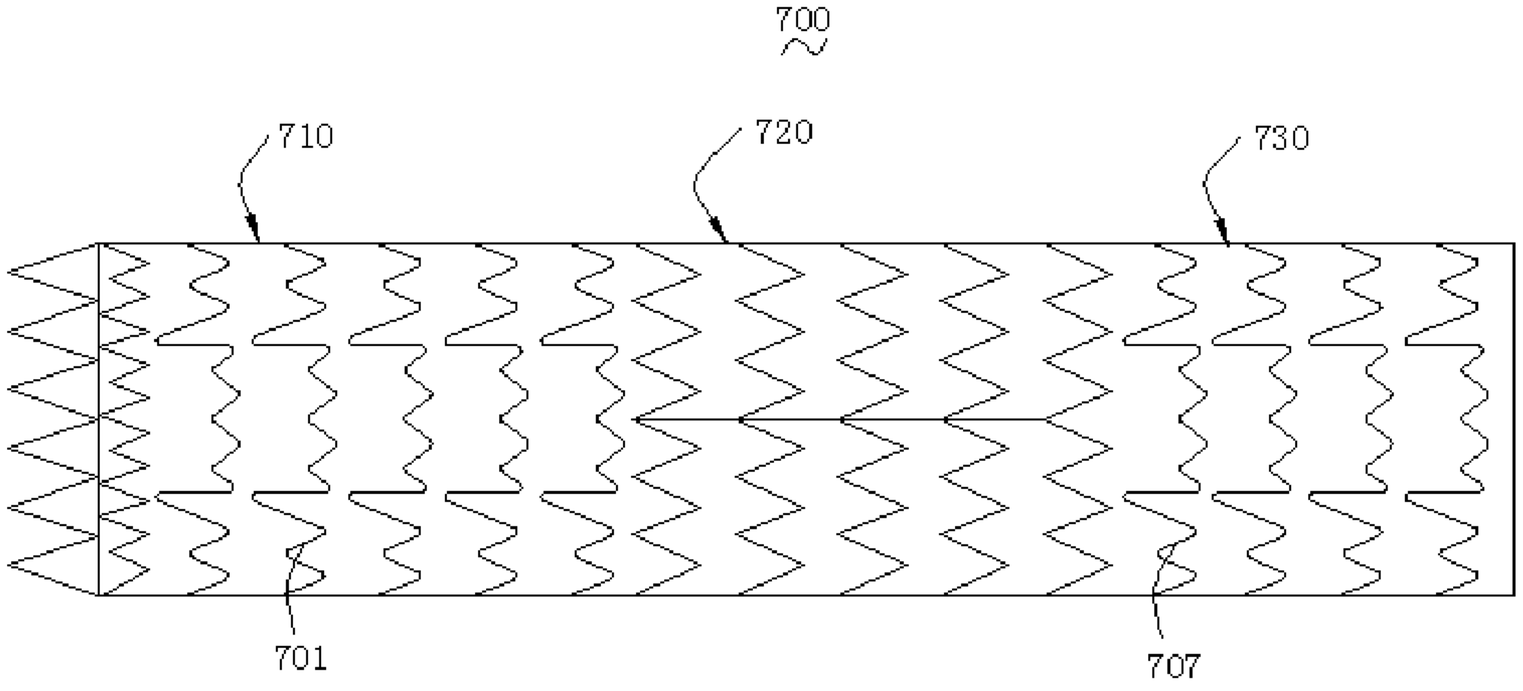

Fig.22

COVERED STENT

FIELD

The disclosure relates to the technical field of medical apparatuses, and in particular, to a stent graft.

BACKGROUND

An aneurysm is a common vascular disease, mostly occurring in the elderly, which easily leads to the rupture of aortic aneurysms and poses a great threat to the life of patients. General surgery was considered as the only way to treat aortic aneurysms, but this method is extremely dangerous.

With the continuous development of medical technology, surgeries such as a minimally invasive surgery which implants a stent graft into a human body for treatment of aortic aneurysm and dissecting aneurysm are being used more and more. In this treatment method, an artificial stent graft is compressed into a delivery device, and guided into a human body along a previously implanted guide wire, where the stent graft is released to a lesion position. A tumor cavity is isolated to form a new blood flow channel, and after an aneurysm loses blood flow supply, residual blood in the tumor cavity gradually forms blood clots and is muscularized into vascular tissues, and a tumor wall in an expanded state contracts due to negative pressure and gradually returns to an original state, thereby achieving the treatment of the aneurysm.

At present, the stent graft mainly includes a plurality of metal rings which are sequentially arranged in a spaced manner, and a membrane fixed to the plurality of metal rings to connect the plurality of metal rings. Due to the fact that the adjacent metal rings are merely in a flexible connection through the membrane, and due to the lack of rigid constraints, the metal rings are easily shortened during stent release and post-operation long-term use, so the stent can possibly enter a tumor cavity when the stent shortens from a distal end to a proximal end, leading to a failure to completely cover a tumor body by the stent graft, and causing a type I internal leakage. In order to avoid the above situation, the prior art mostly adopts an additional rigid connector between the adjacent metal rings to prevent the stent from shortening.

However, the rigid connector limits the bending direction of the stent so that the stent can only be curved towards a side facing away from the connector. As a result, the rigid connector is usually placed on a greater curvature side of the stent. However, blood vessels of the human body are complicated in structure and are usually in a curved state. Since the stent cannot be bent arbitrarily due to the rigid connector, the stent cannot be easily adapted to the shapes of the blood vessels.

SUMMARY

The technical problem to be solved by the present disclosure is to provide a stent graft capable of being bent in all directions to overcome the above-mentioned defects in the prior art.

In order to solve the technical problem, the technical solution of the disclosure is as follows:

Provided is a stent graft, including a plurality of wavy rings and a membrane connected and fixed to the plurality of wavy rings. The stent graft includes, in a circumferential direction, at least one keel region and a non-keel region

connected with the keel region, wherein the shortening rate of the keel region is less than the shortening rate of the non-keel region, and the shortening rate of the keel region is 10-40%.

Provided is a stent graft, including a first body section and a second body section connected with the first body section, which are distributed in the axial direction, wherein the axial shortening rate of the first body section is 10-40%, and the axial shortening rate of the second body section is zero.

In summary, the stent graft of the disclosure has the following beneficial effects: the stent graft of the application which is of an axial compressible structure can be bent towards all directions, the stent graft is provided with at least one keel region and a non-keel region, the shortening rate of the stent graft compressed in the axial direction in the keel region is less than the shortening rate of the stent graft compressed in the axial direction in the non-keel region, and when the stent graft is bent, the wavy rings in the keel region are prone to abutting against each other to form a rigid axial supporting structure on the stent graft to prevent the stent graft from continuing to shorten, therefore, the stent graft of the application can not only meet various bending requirements on a stent, but can also provide enough axial supporting force for the stent.

BRIEF DESCRIPTION OF THE DRAWINGS

The disclosure will be further described in combination with accompanying drawings and embodiments. In drawings:

FIG. **1** is a structural schematic diagram of a straight tubular stent graft provided by a first preferred embodiment of the present disclosure in a bent state;

FIG. **2** is a structural schematic diagram of the stent graft shown in FIG. **1** in a natural state;

FIG. **3** is a structural schematic diagram of a bent stent graft provided by a first preferred embodiment of the present disclosure;

FIG. **4** is an enlarged view of a portion G of the stent graft shown in FIG. **3**;

FIG. **5** is a structural schematic diagram of a first bent segment of the stent graft shown in FIG. **3** after being straightened along a first profile line;

FIG. **6** is a structural schematic diagram of wavy rings of the stent graft shown in FIG. **3** after being re-arranged in an axial direction according to a wave spacing between the wavy rings at the first profile line and covered with membranes;

FIG. **7** is a structural schematic diagram of the wavy rings of the stent graft shown in FIG. **1** which abut against each other;

FIG. **8** is a structural schematic diagram of keel regions of the stent graft shown in FIG. **1** that are distributed on an outer surface of the stent graft;

FIG. **9***a* is a schematic diagram of the stent graft shown in FIG. **1** with a wave included angle being 60°;

FIG. **9***b* is a schematic diagram of the stent graft shown in FIG. **1** with a wave included angle being 90°;

FIG. **9***c* is a schematic diagram of the stent graft shown in FIG. **1** with a wave included angle being 130°;

FIG. **10***a* is a schematic diagram of adjacent second wavy segments of the stent graft shown in FIG. **1** being opposite in phase when the adjacent second wavy segments have no overlap in the axial direction;

FIG. **10***b* is a schematic diagram of the adjacent second wavy segments of the stent graft shown in FIG. **1** being

identical in phase when the adjacent second wavy segments have no overlap in the axial direction;

FIG. **10***c* is a schematic diagram of the adjacent second wavy segments of the stent graft shown in FIG. **1** having a phase difference when the adjacent second wavy segments have no overlap in the axial direction;

FIG. **11** is a schematic diagram of the adjacent second wavy segments of the stent graft shown in FIG. **1** which have overlaps in the axial direction;

FIG. **12** is a structural schematic diagram of a stent graft provided by a second preferred embodiment of the present disclosure;

FIG. **13** is a structural schematic diagram of a stent graft provided by a third preferred embodiment of the present disclosure;

FIG. **14** is a structural schematic diagram of a stent graft provided by a fourth preferred embodiment of the present disclosure;

FIG. **15** is a structural schematic diagram of the stent graft shown in FIG. **14** after being bent in a direction indicated by a first arrow;

FIG. **16** is a structural schematic diagram of the stent graft shown in FIG. **14** after being bent in a direction indicated by a second arrow;

FIG. **17** is a structural schematic diagram of a stent graft according to a fifth embodiment of the present disclosure;

FIG. **18** is a structural schematic diagram of the stent graft shown in FIG. **17** after being expanded;

FIG. **19** is a structural schematic diagram of the stent graft shown in FIG. **17** after being implanted into an aortic arch;

FIG. **20** is a structural schematic diagram of a stent graft according to a sixth embodiment of the present disclosure;

FIG. **21** is a structural schematic diagram of the stent graft shown in FIG. **20** after being expanded;

FIG. **22** is a structural schematic diagram of a stent graft according to a seventh embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE EMBODIMENTS

In order that the technical features, objects and effects of the present embodiments may be more clearly understood, specific embodiments thereof will now be described in detail with reference to the accompanying drawings.

It should be noted that "distal" and "proximal" are used as orientation words, which are customary terms in the field of interventional medical apparatuses, the "distal" means an end away from an operator during a surgical procedure, and the "proximal" means an end close to the operator during the surgical procedure. An axial direction refers to a direction which is parallel to the connecting line of a distal center and a proximal center of a medical apparatus; a radial direction refers to a direction perpendicular to the axial direction; and the distance from the axis refers to the distance reaching the axis in the radial direction.

As shown in FIG. **1**, a first preferred embodiment of the present disclosure provides a stent graft which is substantially of an open-ended and hollow tubular structure, the stent graft including a plurality of wavy rings **101**, and membranes **200** fixed to the plurality of the wavy rings **101** to connect the plurality of the wavy rings **101**.

The membranes **200** are tubular cavity structures where the middle is closed and the ends are opened, and made of high molecular materials having good biocompatibility, such as e-PTFE, PET, or the like. The membranes **200** are fixed to the plurality of wavy rings **101** and enclosed to form a tube cavity with a longitudinal axis, and the tube cavity serves as a channel through which blood flows when the stent graft is implanted into a blood vessel.

The wavy rings **101** are made of materials having good biocompatibility, such as nickel titanium, stainless steel, or the like. The plurality of wavy rings **101** are arranged sequentially in a spaced-apart manner from a proximal end to a distal end, and preferably arranged in a parallel spaced manner. Each wavy ring **101** is of a closed cylindrical structure, and includes a plurality of proximal vertices **102**, a plurality of distal vertices **103**, and supporting bodies **104** connecting the adjacent proximal vertices **102** and distal vertices **103**, and the proximal vertices **102** and distal vertices **103** are wave crests and troughs of corresponding waves, respectively. The plurality of wavy rings **101** have the same or similar wavy shapes, for example, the wavy rings **101** may be a Z-shaped wave, an M-shaped wave, a V-shaped wave or sinusoidal wave structures, or of other structures that are radially compressible to a very small diameter. It will be appreciated that the embodiment does not limit the specific structures of the wavy rings **101**, the wave shapes of the wavy rings **101** may be set as required, and the number of waves and the heights of the waves in each wavy ring **101** may be set as required.

The stent graft may be prepared as follows: weaving a metal wire into a required wave shape, the metal wire may be a nickel-titanium alloy wire with a wire diameter of, for example, 0.35 mm; and after heat setting, surrounding two end portions of the metal wire with a steel jacket and fixing by mechanical pressing so that the metal wire and the steel jacket are connected and fastened to form a metal ring. After all the wavy rings **101** are manufactured, surfaces of the wavy rings **101** which are sequentially arranged are covered with membranes. For example, inner surfaces and outer surfaces of the plurality of wavy rings **101** may be integrally covered with e-PTFE membranes so that the plurality of wavy rings **101** are located between two membranes **200**, and the e-PTFE membranes of an inner layer and an outer layer are bonded together by high-temperature pressing, thereby fixing the plurality of wavy rings **101** between the two membranes. It will be appreciated that, in other embodiments, the wavy rings **101** may also be sutured to PET membranes.

Of course, when formed by integrally cutting a metal tube, the wavy rings **101** are not required to be fixedly connected by the steel jacket. Alternatively, the wavy ring may be formed by welding two end points of the metal wire.

Referring to FIG. **2**, the stent graft includes, in a circumferential direction, at least one keel region **100***a* and a non-keel region **100***b* connected with the keel region **100***a*, the keel region **100***a* and the non-keel region **100***b* both extending in the axial direction of the stent graft, and the region enclosed by the dotted lines in FIG. **2** is the keel region **100***a*.

The axial shortening rate of the keel region **100***a* of the stent graft is less than the axial shortening rate of the non-keel region **100***b*, and the axial shortening rate of the stent graft in the keel region **100***a* is 10-40%.

A method for calculating the shortening rate of the stent graft in the axial direction is as follows: taking the length of the stent graft, which is in a straight tubular shape, in the axial direction in a natural state as r and the diameter of the stent graft as d**1**, surrounding an inner tube with the diameter of d**2** (d**2** is less than d**1**, preferably d**2** is equal to 90%*d**1**) with the stent graft, applying pressure F (1N≤F≤52N) in the axial direction to the stent graft till the stent graft cannot shorten anymore to obtain the total length s, and calculating

the axial shortening rate of the stent graft according to the formula (r-s)/r×100%. Where: (r-s) is an available maximum shortening value of the stent graft. The stent graft surrounds the inner tube for shortening, so that the phenomenon that the stent graft is folded when shortening can be effectively avoided, that is, (r-s) of the present application is the available maximum shortening value when the stent graft is not folded.

When the stent graft is in a frustum shape, that is, the diameters of the two ends of the stent graft are different, the length of the stent graft in the axial direction in the natural state is r, the diameter of the large end is d**1**, the diameter of the small end is d**3**, the stent graft surrounds a conical inner tube or a frustum inner tube with the same taper as the stent graft, and the perpendicular distance between the stent graft and the conical inner tube or the frustum inner tube is 0.05d1. The position of the small end of the stent graft is fixed and unchanged, the pressure F (1N≤F≤2N) in the axial direction is applied to the large end, and the total length of the stent graft when the stent graft cannot shorten anymore is s, and thus the shortening rate of the stent graft in the axial direction is (r-s)/r 100%. Where: (r-s) is an available maximum shortening value of the stent graft. The stent graft surrounds the inner tube for shortening, so that the phenomenon that the stent graft is folded when shortening can be effectively avoided, that is, (r-s) of the present application is the available maximum shortening value when the stent graft is not folded.

When the stent graft itself is manufactured into a bent shape, as shown in FIG. **3**, the stent graft includes a first bent section **400***a* and a second bent section **400***b*, the first bent section **400***a* has a first profile line **401***a* on a greater curvature side of the first bent section **400***a* and a second profile line **402***a* on a lesser curvature side of the first bent section **400***a*, and the second bent section **400***b* has a third profile line **401***b* on a greater curvature side of the second bent section **400***b* and a fourth profile line **402***b* on a lesser curvature side of the second bent section **400***b*. At this time, there are two methods for calculating the shortening rate of the bent section of the stent graft. One method is as follows: referring together to FIG. **4**, by taking the first bent section **400***a* as an example, partitioning the first bent section **400***a* with a plane **109** perpendicular to the axial direction of the stent graft; and cutting a plurality of notches **403** in the membranes **200** close to the second profile line **402***a*. The sizes of the notches **403** can ensure that the stent graft is straightened along the first profile line **401***a* (or cutting a plurality of notches **403** in the membranes **200** close to the second profile line **402***a*, so that the sizes of the notches **403** can exactly ensure that the stent graft is straightened along the first profile line **401***a*). After the first bent section **400***a* is straightened as shown in FIG. **5**, obtaining the length r and the diameter d**1** of the straightened first bent section **400***a*; then surrounding an inner tube with a diameter of d**2** (d**2** is less than d**1**, preferably d**2** is equal to 90%*d**1**) with the straightened first bent section **400***a*; applying pressure F (1N≤F≤2N) in the axial direction to the stent graft until the stent graft cannot shorten, so as to obtain the total length s of the region B; and then calculating the axial shortening rate of the stent graft in the region B according to the formula (r-s)/r*100%. The other method is as follows: also by taking the first bent section **400***a* as an example, re-arranging the wavy rings **101** in the axial direction according to the wave spacing between the wavy rings **101** at the first profile line **401***a*, covering the wavy rings **101** with membranes (with the covering materials and a selected process kept consistent with those of the original stent), as shown in FIG. **6**, and then calculating the shortening rate according to the above-mentioned method for calculating the shortening rate.

During the bending of the stent graft, when any one of the keel region **100***a* or the non-keel region **100***b* reaches the available maximum shortening value, a rigid axial supporting structure is formed in the region to prevent the stent graft from continuing to be bent. Referring to FIG. **7**, during the bending of the stent graft, one wavy ring **101** of the stent graft moves in the direction of pressure together with portions of the membranes **200** fixed to the wavy ring **101**; the portions of the membranes **200** fixed to the wavy ring **101** move together with portions of the membranes **200** distributed at the periphery of the wavy ring **101**. The portions of the membranes **200** distributed at the periphery of the wavy ring **101** will immediately pull another wavy ring **101** nearby to move towards one side close to the wavy ring **101** until the wavy ring **101** cannot keep moving, and at this time, a rigid axial supporting structure is formed on the stent graft, so that the stent graft is prevented from continuing to shorten anymore.

When the axial shortening rate of the stent graft in the keel region **100***a* is less than 10%, the shortening rate of the keel region **100***a* is too small, and no matter to which direction the stent graft is bent, the keel region **100***a* easily reaches the available maximum shortening value, and the keel region **100***a* cannot shorten anymore, thereby restricting the stent graft from continuing to be bent. When the axial shortening rate of the stent graft in the keel region **100***a* is greater than 40%, the axial supporting effect of the stent graft is poor, and the stent graft may enter the tumor cavity when the distal end of the stent graft shortens towards the proximal end of the stent graft, thus threatening the life of a patient. When the shortening rate of the stent graft in the keel region **100***a* is 10-40%, the stent graft can be bent towards all directions to adapt to bent blood vessels, and sufficient axial support can be provided to prevent axial shortening for the stent graft, thus maintaining the tube cavity shape of the stent graft. Referring to FIG. **3**, the stent graft may be continuously bent towards different directions to better adapt to a bent blood vessel. Preferably, the axial shortening rate of the stent graft in the keel region **100***a* is 20-30%.

Referring to FIG. **8**, the circumferential angle covered by the keel region **100***a* on an outer surface of the stent graft is ε° which is greater than or equal to 15° and less than or equal to 45°. When ε° is less than 15°, the circumferential angle covered by the keel region **100***a* on the outer surface of the stent graft is small, which may lead to a poor axial supporting effect of the entire stent graft, and the stent graft may easily swing and retract under the impact of blood flow, finally causing the stent graft to retract into the tumor cavity, and endangering the life of the patient. When ε° is greater than 45°, the circumferential angle covered by the keel region **100***a* on the outer surface of the stent graft is large, which is not conducive to stent bending. When ε° is greater than or equal to 15° and less than or equal to 45°, sufficient axial support can be provided for the stent graft, and when the stent graft is applied to a blood vessel with greater curvature, no folding occurs, thereby keeping the tube cavity smooth, and enabling the stent graft to adapt to a wider range of vascular morphology.

Preferably, the circumferential angle ε° covered by each keel region **100***a* on the outer surface of the stent graft is in the range of 20°-30°. In addition, the number of the keel regions **100***a* is two, and the two keel regions **100***a* are symmetrically distributed in the circumferential direction of the stent graft.

As shown in FIG. **2**, the wavy rings **101** include first wavy segments located in the keel regions **100***a* and second wavy segments located in the non-keel region **100***b*, and the wave heights of the first wavy segments are greater than the wave heights of the second wavy segments. Where the wave height of the first wavy segment is L**1**, the wave height of the second wavy segment is L**2**, and L**1** and L**2** meet the condition that L**2**/L**1** is greater than or equal to ⅓ and less than 1. When L**2**/L**1** is less than ⅓, dense distribution of local waves in the keel regions **100***a* is easily caused, which affects the bending property of the stent graft at this position; or sparse distribution of local waves in the non-keel region **100***b* is caused, which results in a poor supporting effect of the stent graft at this position and a high probability of deformation. Preferably, L**2** is greater than or equal to 4 mm and less than or equal to 12 mm, which not only is conducive to processing, but also improves the bending property of the stent graft. Specifically, each first wavy segment includes at least one first proximal vertex **102***a*, at least one first distal vertex **103***a*, and a first supporting body **104***a* connecting the adjacent first proximal vertex **102***a* and first distal vertex **103***a*, and the second wavy segment includes at least one second proximal vertex **102***b*, at least one second distal vertex **103***b*, and a second supporting body **104***b* connecting the adjacent second distal vertex **102***b* and second distal vertex **103***b*. The wave height of the first wavy segment refers to the distance between the first proximal vertex **102***a* and the first distal vertex **103***a* in the axial direction. The wave height of the second wavy segment refers to the distance in the axial direction between the second proximal vertex **102***b* and the second distal vertex **103***b*; and in the illustrated embodiment, the first distal vertex **103***a* and the second distal vertex **103***b* are located in the same plane perpendicular to the longitudinal central axis of the stent graft.

The distance in the axial direction between the first proximal vertex **102***a* of the first wavy segment of the wavy ring **101** and the corresponding first proximal vertex **102***a* of the adjacent wavy ring **101** is L**3**. L**1** and L**3** meet the condition that L**3**/L**1** is greater than or equal to ¼ and less than or equal to 3/2, so that wave distribution in the keel regions **100***a* is relatively uniform. Preferably, L**1** is greater than or equal to 8 mm and less than or equal to 18 mm, and most preferably, L**1** is greater than or equal to 12 mm and less than or equal to 14 mm.

Since the wavy ring **101** has at least one wave crest with high wave height in the keel region **100***a* and the plurality of distal vertices **103** are located in the same plane perpendicular to the longitudinal axis, when the stent graft shortens, the first proximal vertex **102***a* of one wavy ring **101** easily abuts against another wavy ring **101**, and the wavy rings **101** in the keel region **100***a* abut against each other. When the wavy rings **101** in the keel region **100***a* abut against each other, a rigid axial supporting structure is formed on the stent graft to prevent the stent from continuing to shorten. By arranging the keel regions **100***a* on the stent graft, various bending requirements of the stent graft can be met, and sufficient axial supporting force can be provided for the stent graft, thereby preventing the stent graft from shortening into the tumor cavity.

In this embodiment, each first wavy segment includes one first proximal vertex **102***a* therein, a connecting line between the first proximal vertices **102***a* of two adjacent first wavy segments is parallel to the axis of the stent graft, and the first supporting bodies **104***a* connected with two sides of the first proximal vertex **102***a* are symmetrically disposed with respect to the axis of the stent graft.

Further, the first wavy segment of the keel region **100***a* has a wave included angle of 30°-60°, and the second wavy segment of the non-keel region **100***b* has a wave included angle of 70°-120°. The wave included angle refers to an included angle between the supporting bodies **104** connected with the two sides of the same proximal vertex **102** or distal vertex **103**.

When in-situ fenestration is carried out on the stent graft, a puncture device is used to puncture a small hole in the stent graft, and the small hole is dilated to a required size by the use of a balloon. Referring to FIGS. **9***a*, **9***b* and **9***c*, the wave heights of the wavy rings **101** in FIGS. **9***a*, **9***b* and **9***c* are the same, and the wave included angles are 60°, 90° and 130°, respectively. A balloon with a diameter of D**1** (preferably D**1** being 3-18 mm) is used to expand a circle of the same size at the corresponding position of each wavy ring **101**, where the corresponding position herein refers to a position where the distance of a connecting line, in the axis direction of the stent graft, between the circle center of the balloon and a proximal vertex of the wavy ring **101** in each of FIGS. **9***a*, **9***b* and **9***c*, is equal. The hatched lines in the figures indicate the shapes of windows expanded by the balloon, and it can be seen from the figures that when the wave included angle is 90° or 130°, the windows meeting the size requirements may be expanded, while the wavy ring **101** with the wave included angle being 60° may limit the fenestration size so that a fenestration edge follows the wavy ring **101**. In the figures, the region of the wavy ring **101** covered by a circle with a diameter of D**2** (D**2**=110% D**1**) is a region where the wavy ring **101** supports the fenestration edge, that is, the greater the corresponding angle δ of an intersection of the wavy ring **101** and the circle with the diameter of D**2**, the higher the supporting effect that the wavy ring **101** provides for the fenestration edge. As can be seen from the figures, the larger the wave included angle, the smaller the corresponding angle δ of the intersection of the wavy ring **101** and the circle with the diameter of D**2**, leading to a failure to provide sufficient support for the fenestration edge by the wavy ring **101**.

As can be seen from the above, when the wave included angle of the wavy ring **101** in a certain region is large, the wavy ring **101** does not limit the fenestration size, thereby being beneficial to the fenestration; however, if the wave included angle is too large, the fenestration edge is caused to be far away from the wavy ring **101**, and the wavy ring **101** cannot provide enough support for the fenestration edge; and if the fenestration edge lacks the support from the wavy ring **101**, the window may be further expanded under the action of a radial force of a branch stent, finally leading to the separation of the branch stent from the stent graft. In addition, if the wave included angle of the wavy ring **101** is too large, the number of waves distributed in the circumferential direction of the stent graft in the region is too small, which is not conducive to maintaining the tubular cavity shape of the stent graft. However, when the wave included angle of the wavy ring **101** in a certain region is small, although enough support may be provided for the fenestration edge, the fenestration size may be limited, so that the fenestration size does not meet the size of a branch vessel. In addition, the wavy ring **101** has a certain rigidity and is not prone to deformation under the action of external force, and after a fenestration device is abutted against the wavy ring **101**, the wavy ring **101** is easily broken, or the wavy ring **101** is excessively displaced with respect to the membrane **200**, so that the radial supporting effect of the stent graft is affected.

According to the application, with the arrangement of the keel regions **100***a* and the non-keel region **100***b* with different shortening rates in the circumferential direction of the stent graft, and the adjustment on the wave included angles of the keel regions **100***a* and the non-keel region **100***b*, the non-keel region **100***b* can meet the requirements of in-situ fenestration, and the keel regions **100***a* can meet the requirement of axial supporting force, so that the stent graft is prevented from shortening into a tumor cavity.

A plurality of second wavy segments of the non-keel region **100***b* are arranged in a spaced manner in the axial direction, and when the adjacent second wavy segments are different in phase, the areas available for fenestration between the adjacent second wavy segments are different. FIGS. **10***a*, **10***b* and **10***c* are sequential schematic diagrams of the adjacent second wavy segments being opposite in phase, being identical in phase, and having a phase difference, in the case that the wave structures and wave spacings of the adjacent second wavy segments are identical when the adjacent first wavy segments have no overlap in the axial direction. The term "being opposite in phase" means that the wave crests of the second wavy segment are opposite to the wave troughs of the adjacent second wavy segment, the term "being identical in phase" means that the wave crests of the second wavy segment are opposite to the wave crests of the adjacent second wavy segment, and the "phase difference" means that the wave crests of the second wavy segment are staggered with the wave crests and troughs of the adjacent second wavy segment. As can be seen from the figures, when the adjacent second wavy segments are opposite in phase, the area available for fenestration between the adjacent second wavy segments is at a maximum, and when the adjacent second wavy segments are identical in phase, the area available for fenestration is at a minimum. However, when the adjacent second wavy segments are identical in phase, fenestration regions are distributed more uniformly.

In order to meet the fenestration requirement of the stent graft, different phase conditions may be adapted by adjusting the wave height and the ratio of the wave height to the wave spacing of the second wavy segment of the non-keel region **100***b*. In the case that the second wavy segments have no overlap in the axial direction, when the connecting line between the wave crest of the second wavy segment and the corresponding wave crest of the adjacent second wavy segment is parallel to a rail of the stent graft, the ratio of the wave height of the second wavy segment to the spacing between the adjacent second wavy segments is ⅓-1, and the wave height of the second wavy segment is 4-12 mm. When the connecting line between the wave crest of the second wavy segment and the corresponding wave trough of the adjacent second wavy segment is parallel to the rail of the stent graft, the ratio of the wave height of the second wavy segment to the spacing between the adjacent second wavy segments is ¼-¾, and the wave height of the second wavy segment is 4-14 mm. When the connecting line between the wave crest of the second wavy segment and the corresponding wave crest of the adjacent second wavy segment is inclined with respect to the rail of the stent graft, the ratio of the wave crest of the second wavy segment to the spacing between the adjacent second wavy segments is ¼-1, and the wave height of the second wavy segment is 4-14 mm. As shown in conjunction with FIG. **11**, in the case that the adjacent second wavy segments have overlaps in the axial direction, the ratio of the wave height of the second wavy segment to the spacing between the adjacent second wavy segments is 1-3, and the wave height of the second wavy segment is 5-15 mm. The corresponding wave crest here refers to the wave crest of the adjacent second wavy segment that has the shortest connecting distance between the wave crest of the second wavy segment and a wave crest of the adjacent second wavy segment compared to other wave crests of the adjacent second wavy segment; and the corresponding wave trough here refers to the wave trough of the adjacent second wavy segment that has the shortest connecting distance between the wave trough of the second wavy segment and the wave trough of the adjacent second wavy segment compared to other wave troughs of the adjacent second wavy segment.

As shown in FIG. **8**, the non-keel region **100***b* includes two sub-regions, namely a greater curvature side region **110** and a lesser curvature side region **111**, that are distributed in the circumferential direction. The wave included angle of the greater curvature side region **110** is 80°-100°, preferably 90°, and the wave included angle of the lesser curvature side region **111** is 75°-95°, preferably 80°. The ratio of the wave height of the second wavy segment on the greater curvature side region **110** to the wave height of the second wavy segment on the lesser curvature side region **111** is 0.7-1, the ratio of the wave spacing between the adjacent second wavy segments on the greater curvature side region **110** to the wave spacing on the lesser curvature side region **111** is 0.7-1, and the ratio of the area covered by the greater curvature side region **110** on the outer surface of the stent graft to the area covered by the lesser curvature side region **111** on the outer surface of the stent graft is 0.7-1.3. In the illustrated embodiment, the ratio of the area covered by the greater curvature side region **110** on the outer surface of the stent graft is equal to the area covered by the lesser curvature side region **111** on the outer surface of the stent graft, the wave heights of the second wavy segments on the greater curvature side region **110** are equal, and the wave spacings between the adjacent second wavy segments on the greater curvature side region **110** are equal. Also, the wave heights of the second wavy segments on the lesser curvature side region **111** are equal, and the wave spacings between the adjacent second wavy segments on the lesser curvature side region **111** are equal.

In the illustrated embodiment, the greater curvature side region **110** and the lesser curvature side region **111** are disposed opposite to each other in the circumferential direction, and the keel regions **100***a* are connected between the greater curvature side region **110** and the lesser curvature side region **111**. It will be appreciated that the non-keel region **100***b* may also be divided into three or more circumferentially distributed sub-regions as desired, the sub-regions may be arranged in a spaced manner or continuously, and the wave shapes, the number of waves, the wave heights, and the wave angles of the wavy segments of each sub-region may be set as desired.

Further, referring to FIGS. **1** and **2**, the stent graft further includes at least one proximal wavy ring **101***a* at one end of the plurality of wavy rings **101**.

The axial shortening rate between the proximal wavy ring **101***a* and its adjacent wavy ring **101** is less than 10%, so as to enhance the axial supporting effects of the end portions of the stent graft, and to prevent the two ends of the stent graft from causing the stent graft to swing under the impact of the blood flow.

When the number of the proximal wavy rings **101***a* is two or more, the axial shortening rate between the two or more proximal wavy rings **101***a* is less than 3%, so as to enhance the axial supporting effect of the end portions of the stent graft, and to prevent the end portions of the stent graft from causing the stent graft to swing under the impact of the blood

flow. Preferably, the axial shortening rate between the two or more proximal wavy rings **101***a* is zero.

It will be appreciated that at least one distal wavy ring (not shown) may be disposed at the other end of the plurality of wavy rings **101** and the axial shortening rate between the distal wavy ring and the adjacent wavy ring **101** is less than 10%. When the number of the distal wavy rings is two or more, the axial shortening rate between the two or more distal wavy rings is less than 3%, preferably 0.

Both the proximal wavy ring and the distal wavy ring are made of materials having good biocompatibility, such as nickel titanium, stainless steel or the like. The proximal wavy ring and the distal wavy ring both have closed cylindrical structures. The proximal wavy ring and the distal wavy ring may be a Z-shaped wave, an M-shaped wave, a V-shaped wave or sinusoidal wave structures, or of other structures that are radially compressible to a very small diameter. It will be appreciated that not only the numbers of the proximal wavy ring and the distal wavy ring may be set as desired, but also the wave shapes, the number of waves, and the wave heights of the proximal wavy ring and the distal wavy ring may be set as desired.

Further, the stent graft further includes an anchoring bare stent **105** located at one end or the distal end of the stent graft and connected with the proximal wavy ring or the distal wavy ring.

FIG. **12** shows a stent graft provided by a second preferred embodiment of the present disclosure, which differs from the first embodiment in that each keel region **100***a* includes one first proximal vertex **102***a*, and the connecting line between the first proximal vertices **102***a* of two adjacent wavy rings **101** is inclined with respect to the axis of the stent graft.

FIG. **13** shows a stent graft provided by a third preferred embodiment of the present disclosure, which differs from the first embodiment in that the wavy ring **101** further includes a third wavy segment in the keel region **100***a*. The wave height L**1** of the first wavy segment is greater than the wave height L**6** of the third wavy segment.

The third wavy segment includes at least one third proximal vertex **102***c*, at least one third distal vertex **103***c*, and a third supporting body **104***c* connecting the adjacent third proximal vertex **102***c* and third distal vertex **103***c*, and the wave height L**6** of the third wavy segment refers to the axial distance between third proximal vertex **102***c* and the third distal vertex **103***c*.

In the illustrated embodiment, the wave height L**6** of the third wavy segment is equal to the wave height L**2** of the second wavy segment, and the first distal vertex **103***a*, the second distal vertex **103***b*, and the third distal vertex **103***c* are located in the same plane perpendicular to the longitudinal central axis of the stent graft. It will be appreciated that, in other embodiments, the wave height L**6** of the third wavy segment and the wave height L**2** of the second wavy segment may also be unequal, and the first distal vertex **103***a*, the second distal vertex **103***b* and the third distal vertex **103***c* need not be located in the same plane perpendicular to the longitudinal central axis of the stent graft.

FIG. **14** shows a stent graft provided by a fourth preferred embodiment of the present disclosure, which differs from the first embodiment in that the first supporting bodies **104***a* that are connected to one side of the first proximal vertices **102***a* and close to the greater curvature side region **110** are distributed in the axial direction parallel to the stent graft, and the first supporting bodies **104***a* that are connected to the other side of the first proximal vertices **102***a* and close to the lesser curvature side region **111** are disposed obliquely with respect to the axis direction of the stent graft.

When the stent graft of FIG. **14** is bent in a direction indicated by a first arrow **500**, referring to FIG. **15**, the first supporting bodies **104***a* adjacent to the greater curvature side region **110** of the adjacent first wavy segments abut against each other to form an axial support, and the included angle between the first supporting bodies **104***a* adjacent to the greater curvature side region **110** of the adjacent first wavy segments is η°. When the stent graft of FIG. **14** is bent in a direction indicated by a second arrow **600**, referring to FIG. **16**, the first supporting bodies **104***a* adjacent to the lesser curvature side region **111** of the adjacent first wavy segments abut against each other to form an axial support, and the included angle between the first supporting bodies **104***a* adjacent to the lesser curvature side region **111** of the adjacent first wavy segments is θ°. As can be seen from the figures, η° is less than θ°. When the first supporting bodies **104***a* of the adjacent first wavy segments abut against each other to form the axial support, the greater the included angle between the first supporting bodies **104***a* of the adjacent first wavy segments, the smaller the force distributed to the axial direction of the stent graft, and the poorer the axial supporting effect on the stent graft. Therefore, the axial supporting effect formed when the first supporting bodies **104***a* are distributed parallel to the axial direction of the stent graft abutting against each other in FIG. **15** is superior to the axial supporting effect formed when the first supporting bodies **104***a* are disposed obliquely with respect to the axial direction of the stent graft abutting against each other in FIG. **16**. Meanwhile, when the included angle between the first supporting bodies **104***a* of the adjacent first wavy segments is greater, excessive deformation of the membranes of the keel regions **100***a* is easily caused to bring about an uneven surface of the stent graft, thus leading to a high probability of thrombosis.

When the first supporting bodies **104***a* distributed in the axial direction parallel to the stent graft abut against each other to form the axial support, the included angle between the first supporting bodies **104***a* of the adjacent first wavy segments is the smallest, and the axial supporting force of the stent graft is the highest. Therefore, the first supporting bodies **104***a* distributed in the axial direction parallel to the stent graft are disposed on one side close to the greater curvature side region **110**, and when the stent graft is bent towards the lesser curvature side, the first supporting bodies may provide enough axial supporting force for the stent graft, and the axial supporting effect on the stent graft is optimal.

Referring to FIG. **17**, a fifth preferred embodiment of the present disclosure provides a stent graft **500**, including a first body section **510** and a second body section **520** connected with the first body section **510**, which are distributed in the axial direction. The axial shortening rate of the first body section **510** is 10-40%, and the axial shortening rate of the second body section **520** is zero. The axial shortening rate of the first body section **510** is measured by a method including the following steps of: in a natural state, taking the length of the first body section **510** as a and the diameter as d, surrounding the first body section **510** with an inner tube with a diameter of 0.9 d, applying pressure of 1-2N in the axial direction to two ends of the first body section **510** until no shortening (no folding) occurs to obtain the length b, and calculating the axial shortening rate of the first body section **510** according to the formula (a-b)*100%/a. When the length of the first body section **510** reaches (a-b), a rigid axial support may be formed on the first body section **510**.

In use, the first body section **510** is placed into a bent section (a position where the curvature radius is smaller) of the aortic arch, and the second body section **520** is placed into a straight section (a position where the curvature radius is greater) of the aortic arch. The first body section **510** can axially shorten, that is, the first body section **510** has certain flexibility in the axial direction, so that the first body section **510** generates no straightening force while conforming to the bent configuration of the aortic arch, so that the safety of the operation is improved. However, the second body section **520** cannot axially shorten, so that the second body section **520** can be prevented from shortening under the action of the blood flow, and the end portions of the second body section **520** are prevented from retracting into the tumor cavity to endanger the life of a patient. Preferably, the axial shortening rate of the first body section **510** is 20-30%, so that the first body section **510** can better conform to the bent configuration of the aortic arch, and a relatively stable axial supporting structure can be formed, thereby reducing the risk of shortening of the first body section **610** after implantation.

In the present embodiment, the length of the first body section **510** is 50-100 mm, so that the first body section **510** is able to cover the bent section in the aortic arch.

Specifically, the first body section **510** and the second body section **520** are both open-ended and hollow straight tubular structures. Referring together to FIG. **18**, the first body section **510** includes a plurality of first wave loops **501** arranged in a spaced manner in the axial direction and a first membrane **502** covering the first wave loops **501**. The second body section **520** includes a plurality of second wave loops **503** arranged in the axial direction, a connector **505** connecting the adjacent second wave loops **503**, and a second membrane **504** covering the second wave loops **503** and the connector **505**. The first membrane **502** and the second membrane **504** are tubular cavity structures that are closed in the center and are open-ended, and are made of high molecular materials having good biocompatibility, such as e-PTFE, PET, or the like. The first membrane **502** which is fixed to the first wave loops **501**, and the second membrane **504** which is fixed to the second wave loops **503** and the connector **505**, are respectively enclosed to form a tube cavity with a longitudinal axis, and after the stent graft is implanted into a blood vessel, the tube cavity serves as a channel through which blood flows. The first wave loops **501**, the second wave loops **503** and the connector **505** are made of materials having good biocompatibility, such as nickel titanium, 316L medical stainless steel, or the like. The first wave loops **501** and the second wave loops **503** may be a Z-shaped wave, an M-shaped wave, a V-shaped wave or sinusoidal wave structures, or of other structures that are radially compressible to a very small diameter. In actual preparation, the closed first wave loops **501** and second wave loops **503** are formed by weaving nickel-titanium wires or cutting and shaping nickel-titanium tubes, with surfaces of the first wave loops **501** and the second wave loops **503** covered with membranes, and the first wave loops **501** and the second wave loops **503** are respectively fixed to the first membrane **502** and the second membrane. **504** by means of sewing or high-temperature pressurization, or the like.

It should be noted that the first body section **510** and the second body section **520** are only distinguished for convenience of explanation and do not mean that the connection boundary of the stent graft **500** is broken, and the first body section **510** and the second body section **520** are of an integral structure, that is, the first membrane **502** and the second membrane **504** may be of an integral structure.

With continued reference to FIG. **17**, the first body section **510** includes, in a circumferential direction, keel regions **511** and a non-keel region **512** connected with the keel regions **511**, where the axial shortening rates of the keel regions **511** are less than the axial shortening rate of the non-keel region **512**, and the axial shortening rates of the keel regions **511** are 10-40%. When the first body section **510** is bent, a rigid axial supporting structure may be formed in the keel regions **511**. Referring together to FIG. **18**, the number of the keel regions **511** is two, and the two keel regions **511** are substantially symmetrically distributed along the connector **505**, so that the first body section **510** may better conform to the anatomical structure of the aortic arch. The first body section **510** is prevented from generating additional stress and twisting forces during bending, the first body section **510** is prevented from swinging under the action of the blood flow, the stability of the first body section **510** is improved in the bent state, and the life of the stent graft **500** may be prolonged. It should be noted that the statement that the two keel regions **511** are substantially symmetrically distributed along the connector **505** means that the difference between the distances from center lines of the two keel regions **511** to the connector **505** may have a deviation of 5%.

Specifically, the first wave loops **501** include first wavy segments **5011** located in the keel regions **511** and second wavy segments **5012** located in the non-keel region **512**, the wave height L**1** of the first wavy segment **5011** is greater than the wave height L**2** of the second wavy segment **5012**, the wave spacing L**3** between two adjacent first wavy segments **5011** is less than the wave spacing L**4** between two adjacent second wavy segments **5012**, and the first wavy segments **5011** of the two keel regions **511** are substantially symmetrically distributed along the connector **505**. The first wavy segment **5011** and the second wavy segment **5012** each include wave crests, wave troughs, and wave rods connecting the adjacent wave crests and troughs. When the first body section **510** is bent, the wave crests and the wave troughs of the first wavy sections **5011** abut against each other to form an axial support, and a relatively large region for fenestration is provided between the second wavy sections **5012**, so that the implantation of a branch stent in the region of the second wavy sections **5012** is facilitated. It should be noted that the wave height of the present application refers to the distance in the axial direction between a wave crest and an adjacent wave trough, and the wave spacing refers to the axial distance between a wave crest and a corresponding wave trough (a wave trough closest to the wave crest) of an adjacent wave loop. Preferably, the ratio of the wave height of the first wavy segment **5011** to the wave height of the second wavy segment **5012** is not greater than 3, and the connecting line between the wave trough of the first wavy segment **5011** of the first wave loop **501** and the wave trough of the second wavy segment **5012** is perpendicular to the plane of the axis of the first body section **510**.

In the illustrated embodiment, the wave heights of the plurality of first wavy segments **5011** are equal, and the wave spacings between every two adjacent first wavy segments **5011** are equal. The wave heights of the plurality of second wavy segments **5012** are also equal, and the wave spacings between every two adjacent second wavy segments **5012** are also equal. The connecting line of the corresponding wave crests of the plurality of first wavy segments **5011** is parallel to the axis of the first body section **510**. Specifi-

cally, the wave height L1 of the first wavy segment **5011** is 6-16 mm, and the wave height L2 of the second wavy segment **5012** is 4-12 mm.

Further, in order to facilitate fenestration in the non-keel region **512**, the included angle between two adjacent wave rods of the second wavy segment **5012** is 80°-100°, so that the area available for fenestration between the two adjacent wave rods is large, and the limitation of the wave rods to the fenestration size is reduced. Preferably, the included angle between two adjacent wave rods of the second wavy segment **5012** is 90°.

Further, the phase difference of the second wavy segment **5012** is zero, that is, the connecting line between the two corresponding wave crests of the adjacent second wavy segment **5012** is parallel to the axis of the first body section **510**, and the connecting line between the two corresponding wave troughs of the adjacent second wavy segment **5012** is parallel to the axis of the first body section **510**. In this way, the shortest distance between any two points on the two adjacent second wavy segments **5012** is large, so that portions available for fenestration in the non-keel region **512** of the first body section **510** are uniformly distributed, the fenestration of the first body section **510** in all positions in the non-keel region **512** is facilitated, and the implantation of the branch stent into the first body section **510** is also facilitated.

With continued reference to FIG. **18**, the included angle between the wave rod of the first wavy segment **5011** close to the connector **505** and the axial direction of the first body section **510** is less than the included angle between the wave rod away from the connector **505** and the axial direction of the first body section **510**. After the stent graft **500** is released to the aortic arch, the included angle between the wave rods of the adjacent first wavy segments **5011** close to the connector **505** can be relatively small, so that the force distributed to the axial direction of the first body section **510** is relatively large, and the axial supporting effect of the first body section **510** is improved advantageously. Specifically, the included angle between the wave rod of the first wavy segment **5011** close to the connector **505** and the axial direction of the first body section **510** is not greater than 15°, and the included angle between the wave rod of the first wavy segment **5011** away from the connector **505** and the axial direction of the first body section **510** is between 20°-60°. Specifically, in the embodiment, the number of the wave rods of the first wavy segment **5011** is two, the included angle between the wave rod close to the connector **505** and the axial direction of the first body section **510** is zero, and the included angle between two adjacent wave rods is 30-60°.

Further, each keel region **511** covers an angle of 15°-45° in the circumferential direction, so that damage to the membranes during bending due to excessively sharp wave crests of the first wavy segments **5011** of the first body section **510** may be avoided, and the risk that the first body section **510** is folded during bending may also be reduced. Preferably, each keel region **511** covers an angle of 20°-30° in the circumferential direction.

Further, the included angle between the connecting line between a middle point of the wave rod of the first wavy segment **5011** close to the connector **505** and the longitudinal central axis of the first body section **510** and the connecting line between the connector **505** and the longitudinal central axis of the first body section **510** is 60°-90°, that is, the angle covered in the circumferential direction by the non-keel region **512** which is between the two keel regions **511** and on the side intersecting with the extension line of the connector **505** is approximately 120°-180°. After the implantation of the aortic arch, the area of the non-keel region **512** that is between the two keel regions **511** on the first body section **510** and located on the greater curvature side of the blood vessel can be relatively large, so that the fenestration on the non-keel region **512** on this side for the implantation of the branch stent is facilitated, and at the same time, the first body section **510** can better conform to the anatomical structure of the aortic arch.

It should be noted that the structure of the second body section **520** may be as shown in the prior art and will not be described in detail herein. In the illustrated embodiment, the shapes and sizes of the second wave loops **503** are identical, and the spacings between two adjacent second wave loops **503** are also equal. The wave heights of the second wave loops **503** are 8-18 mm, and the ratio of the wave spacing to the wave height of two adjacent second wave loops **503** is not greater than ⅓. The number of the connector **505** is one, the connector **505** is linear, and the connector **505** spans all of the second wave loops **503** of the second body section **520**.

It will be appreciated that the second wave loops **503** of the second body section **520** and the connector **505** may also be adjusted according to actual needs, as long as it is ensured that the shortening rate of the second body section **520** is zero.

Referring together to FIG. **19**, in an actual operation, when the stent graft **500** is implanted into the aortic arch, the first body section **510** may be located at a bent portion of the aortic arch, the second body section **520** may be located at a straight portion of the aortic arch, the first wavy segments **5011** of the keel regions **511** may abut against each other to form an axial support, and reconstruction of important branch vessels of three main arteries, including the truncus brachiocephalicus, the left common carotid artery and the left subclavian artery, on the aortic arch may be accomplished by means of in-situ fenestration on the non-keel region **512** located on the greater curvature side of the blood vessel.

Referring to FIG. **20**, the structure of the stent graft **600** according to the second embodiment of the present disclosure is substantially the same as that of the stent graft **500**, except that first wave loops **601** of a first body section **610** are arranged at unequal intervals.

Referring together to FIG. **21**, the wave spacing between first wavy segments **6011** of a keel region **611** is gradually reduced from an end away from the second body section **620** to an end close to the second body section **620**, so that the axial shortening rate of the first body section **610** is gradually reduced from the end away from the second body section **620** to the end close to the second body section **620**, gentle transition to the second body section **620** is achieved, the risk of local compression of a vessel wall caused by the fact that a region where the first body section **610** is connected with the second body section **620** is bulged can be reduced, and the stability of the stent graft **600** is improved. Further, the wave spacing between second wavy segments **6012** of a non-keel region **612** is gradually reduced from an end away from the second body section **620** to an end close to the second body section **620**, so that a window more meeting the size requirement of a branch vessel on the aortic arch can be conveniently opened in the non-keel region **612**, and the improvement of the stability of the branch stent and the stent graft **600** is facilitated.

In the illustrated embodiment, the wave spacing between the first wavy segments **6011** of the keel region **611** is an arithmetic sequence from the end away from the second

body section **620** to the end close the second body section **620**. The wave spacing between the second wavy segments **6012** of the non-keel region **612** is an arithmetic sequence from the end away from the second body section **620** to the end close to the second body section **620**. Specifically, from the end close to the second body section **620**, the wave spacing between the first wavy segment **6011** and the second first wavy segment **6011** is 1 mm, the wave spacing between the second first wavy segment **6011** and the third first wavy segment **6011** is 2 mm, and so on.

It will be appreciated that, in other embodiments, the wave spacing between the first wavy segments **6011** of the keel region **611** may also be adjusted as desired, so long as the shortening rate of the keel region **611** is between 10% and 40%. The wave spacing between the second wavy segments **6012** of the non-keel region **212** may also be adjusted according to the position and size of the branch vessel on the aortic arch.

Referring to FIG. **22**, the structure of a stent graft **700** according to a third embodiment of the present disclosure is substantially the same as that of the stent graft **500**, except that the stent graft **700** further includes a third body section **730** connected to an end of the second body section **720** away from the first body section **710**. The axial shortening rate of the third body section **730** is less than the shortening rate of the first body section **710**, and greater than the axial shortening rate of the second body section **720**.

Although the straight section of the aortic arch is in a relatively gentle (relatively large curvature radius) region in the blood vessel, due to the relatively complicated anatomical structure of the aortic arch, a part of residual straightening force may still exist after the implantation of the second body section **720**; and with the arrangement of the third body section **730** which has an anchoring effect with a vessel wall, a certain stretch restriction effect may be played on the second body section **720** to reduce the acting force of the second body section **720** on the vessel wall, so that the risk of a rupture of the vessel wall is reduced. In addition, the axial shortening rate of the third body section **730** is less than the axial shortening rate of the first body section **710** and greater than the axial shortening rate of the second body section **720**, so that the third body section **730** has a certain bending characteristic and can be prevented from shortening.

With continued reference to FIG. **22**, the third body section **730** includes a plurality of third wave loops **707** arranged in a spaced manner in the axial direction, and the wave spacing between the third wave loops **707** is gradually increased from the end close to the second body section **720** to the end away from the second body section **720**, so that a gentle transition between the second body section **720** and the third body section **730** is achieved, thereby reducing the risk that the stent graft **700** is bulged in use.

The structure of the third body section **730** may be similar to the structure of the first body section **710**, and is not described in detail herein. In the illustrated embodiment, the structure of the third wave loop **707** may be the same as that of the first wave loop **701**, and the third body section **730** with a smaller axial shortening rate may be obtained by reducing the wave spacing of the first wave loop **701**. It will be appreciated that, in other embodiments, the structure of the third body section **730** may also be designed as desired, so long as the axial shortening rate of the third body section **730** is maintained between the axial shortening rate of the first body section **710** and the axial shortening rate of the second body section **720**. For example, the connecting line of the wave crests of each third wave loop **707** is located in a plane perpendicular to the axis of the third body section **730**, and the connecting line of the wave troughs is also located in the plane perpendicular to the axis of the third body section **730**.

The technical features of the above-mentioned embodiments may be combined in any combination. In the interest of brevity, all possible combinations of the technical features in the above embodiments are not described, but all should be considered as within the scope of this Description, except combinations where at least some of such technical features are mutually exclusive.

The above-mentioned embodiments are merely illustrative of several embodiments of the present disclosure, and the description thereof is more specific and detailed, but is not to be construed as limiting the scope of protection of the present disclosure. It should be noted that several modifications and improvements can be made by those ordinarily skilled in the art without departing from the concept of the present disclosure, which fall within the scope of protection of the present disclosure. Therefore, the scope of protection of the present disclosure shall be subject to the appended claims.

The invention claimed is:

1. A stent graft, comprising a plurality of wavy rings and membranes connected and fixed to the plurality of wavy rings, wherein the stent graft comprises, in a circumferential direction, at least one longitudinal keel region and a non-keel region connected with the keel region, wherein the axial shortening rate of the keel region is less than the circumferential shortening rate of the non-keel region, and the axial shortening rate of the keel region is from 10% to 40%;

wherein the non-keel region has a greater curvature side region distributed in the circumferential direction, and a lesser curvature side region distributed in the circumferential direction, and wherein the greater curvature side region and the lesser curvature side region are disposed opposite to each other in the circumferential direction, and the at least one keel region is connected between the greater curvature side region and the lesser curvature side region.

2. The stent graft of claim **1**, wherein each of the at least one keel region covers a circumferential angle of from 15° to 45° on the stent graft.

3. The stent graft of claim **2**, wherein the number of the at least one keel region is two, and the two keel regions are symmetrically disposed in the circumferential direction of the stent graft.

4. The stent graft of claim **1**, wherein the wavy rings comprise first wavy segments located in the at least one keel regions and second wavy segments located in the non-keel region, and the wave heights of the first wavy segments are greater than the wave heights of the second wavy segments.

5. The stent graft of claim **4**, wherein the wave height of the first wavy segment is L**1**, the wave height of the second wavy segment is L**2**, and L**2**/L**1** is greater than or equal to ⅓ and less than 1.

6. The stent graft of claim **5**, wherein L**2** is greater than or equal to 4 mm and less than or equal to 12 mm, and L**1** is greater than or equal to 8 mm and less than or equal to 18 mm.

7. The stent graft of claim **5**, wherein the spacing between the adjacent first wavy segments is L**3**, and L**3**/L**1** is greater than or equal to ¼ and less than or equal to 3/2.

8. The stent graft of claim **7**, wherein the first wavy segments comprise first proximal vertices, and a connecting line between the first proximal vertices of two adjacent first wavy segments is parallel to the axis of the stent graft.

9. The stent graft of claim 8, wherein the first wavy segment further comprises first supporting bodies connected with two sides of the first proximal vertices, the first supporting bodies located on one side of the first proximal vertices are distributed in the axial direction parallel to the stent graft, and the first supporting bodies located on the other side of the first proximal vertices are disposed obliquely with respect to the axial direction of the stent graft.

10. The stent graft of claim 1, wherein the stent graft further comprises at least one proximal wavy ring located at an end of the plurality of wavy rings, wherein the axial shortening rate between the proximal wavy ring and the adjacent wavy ring is less than 10%.

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